Assessment of Energy Efficiency, Electrification, and Decarbonization Potential for the New York State Industrial Sector: Phase Two

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Assessment of Energy Efficiency, Electrification, and Decarbonization Potential for the New York State Industrial Sector: Phase Two

Final Report

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Abstract

The study aimed to identify and estimate the potential for energy savings and greenhouse gas (GHG) emissions reductions in New York State's Industrial Manufacturing sector. The study team assessed multiple fuels by year through 2050 for the whole state, for each of the 11 New York Independent System Operator (NYISO) zones, and by proximity to a disadvantaged community (DAC), a secondary objective aimed to inform the design and planning of decarbonization interventions in the Industrial Manufacturing sector. The study examined the energy and emissions impact of the four decarbonization categories and reported results for technical and economic potential, and achievable potential under specific adoption scenarios. For each scenario and level of potential, the team calculated annual energy savings and emissions as the sum of savings for new measures implemented that year and as rollover savings from measures adopted in prior years.

The study found that New York State's Industrial Manufacturing sector has the technical potential to reduce its energy usage by 21% and GHG emissions by 69% compared to their respective baselines in 2050, and the economic potential to reduce energy usage by 26% and emissions by 40% to 48%. Electrification is the largest source of achievable energy savings potential in New York State's Industrial Manufacturing sector throughout the forecast.

Keywords

Industrial potential, emissions reduction, emissions reduction potential, energy savings, manufacturing, decarbonization

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Acronyms and Abbreviations

$/kW	dollars per kilowatt-hour
~	approximately
ºC	degrees Celsius
AFMMBtu	all-fuels million British thermal units
BCA	benefit-cost analysis
Btu	British thermal unit
CCUS	carbon capture, utilization, and storage
CH_4	methane
CHP	combined heat and power
Climate Act	Climate Leadership and Community Protection Act
CO_2	carbon dioxide
CSP	concentrated solar power
DAC	disadvantages communities
DEC	New York State Department of Environmental Conservation
DOE	U.S. Department of Energy
DPS	New York State Department of Public Service
EIA	U.S. Energy Information Administration
EUL	expected useful life
GHG	greenhouse gas

HGL	hydrocarbon gas liquids
HiCO_2Value	High Carbon Dioxide Value
HVAC	heating, ventilation, and air conditiong
IAC	Industrial Assessment Center
IR	infrared
IRA	Inflation Reduction Act
IRR	Internal Rate of Return
kWh	kilowatt-hour
LBMP	Locational-based marginal price
LBNL	Lawrence Berkeley National Laboratory.
LoCO_2Value	Low Carbon Dioxide Value
MECS	Manufacturing End Use Consumption Survey
million MMBtu	million million British thermal units
MMBtu	million British thermal units
$MTCO_2e$	thousand metric tons of carbon dioxide equivalent
MW	megawatt
N_2O	nitrous oxide
NAICS	North American Industry Classification System
NEIs	nonenergy impacts
NYISO	New York Independent System Operator
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
O&M	operations and maintenance
PSC	Public Service Commission
RF	radio frequency
RGGI	Regional Greenhouse Gas Initiative
RNG	renewable natural gas
ROB	replace-on-burnout
SCT	societal cost test
“Stock Study”	“New York Statewide Industrial Facilities Stock Assessment”
TRM	technical resource manual

Glossary

Btu	British thermal unit. The quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.
Climate Act	New York Climate Leadership and Community Protection Act. Signed into law on July 18, 2019.
DAC	Disadvantaged communities. Communities identified by state agencies, authorities, and entities to direct funding in a manner designed to achieve a goal of receiving 40% of the overall benefits of spending on clean energy and energy efficiency programs, per Climate Act requirements.
Energy consumption	All direct energy used for heat and power at the facility, regardless of where the energy was produced.
Feedstock	Energy sources used for raw material input or any purpose other than the production of heat or power.
Industrial Tiers 1, 2, 3	NYSERDA industrial facility classification; Tier 1 includes facilities with greater than $1 million in annual energy expenditures; Tier 2 consists of those with $500,000 to $1 million; and Tier 3 includes those with less than $500,000 in annual energy expenditures.
IRR	Internal rate of return. A metric used in financial analysis to estimate the profitability of a potential capital investment. The IRR for an investment is the percentage rate earned on each dollar invested for each period it is funded. A higher IRR indicates a higher return on investment.
Low-carbon fuels	Alternative fuels that can replace carbon-intensive fossil fuels, such as natural gas, fuel oil, or coal. This study focuses on hydrogen and renewable natural gas when examining low-carbon fuel decarbonization potential.
Manufacturing facility	A site where the manufacture of products from raw material to finished goods using industrial production equipment and processes has been determined or is believed to be present.
MECS	Manufacturing Energy Consumption Survey. A national sample survey that collects information on the stock of U.S. manufacturing establishments, their energy-related building characteristics, and their energy consumption and expenditures (EIA 2023).
$MTCO_2e$	Metric ton of carbon dioxide equivalent.
NAICS	North American Industry Classification System. A numeric classification system to categorize facilities by processes or production.
NYISO	New York Independent System Operator. A nonprofit organization that manages New York State's electric grid and competitive wholesale electricity market.
NYISO zones	NYISO divides New York into 11 capacity zones for operations, planning, and pricing: (A) West, (B) Genesee, (C) Central, (D) North, (E) Mohawk Valley, (F) Capital, (G) Hudson Valley, (H) Milwood, (I) Dunwoodie, (J) New York City, and (K) Long Island.

Physical unit The physical unit of an energy source is commonly used to measure a specific type of energy or fuel (e.g., barrels or gallons for liquid fuels, short tons for coal, cubic feet for natural gas, and kilowatt-hours (kWh) for electricity).

Retrofit An efficiency measure or program that encourages the replacement of functional equipment before the end of its operating life with higher-efficiency units (also called "early retirement"), or the installation of additional controls, equipment, or materials in existing facilities to reduce energy consumption (e.g., increased insulation, lighting occupancy controls, economizer ventilation systems). This definition comes from the U.S. Environmental Protection Agency's *Guide for Conducting Energy Efficiency Potential Studies* (EPA 2007).

Summary

The New York State (NYS) Public Service Commission (PSC) directed the New York State Energy Research and Development Authority (NYSERDA) to assess the statewide potential for energy efficiency, electrification, and decarbonization in the Industrial sector (DPS 2020). DNV conducted this Industrial Potential Study in consultation with NYSERDA and Department of Public Service (DPS) staff. This study refines and expands the Phase One Industrial Potential Study DNV completed in 2023, which was based on less robust data (NYSERDA 2023a).

S.1 Study Objective

The main objective is to identify and estimate the potential for energy savings and greenhouse gas (GHG) emissions reductions in New York State's Industrial Manufacturing sector. The study team assesses multiple fuels, including electricity, natural gas, and oil, by year through 2050 for the state as a whole, for each of the 11 New York Independent System Operator (NYISO) zones, and by proximity to a disadvantaged community (DAC). A secondary study objective is to inform the design and planning of decarbonization interventions in the Industrial sector.

This study focuses on New York State's Manufacturing sector and does not include other sectors that could be considered industrial, such as agriculture, construction, and mining.[1] The primary data source for this study's inputs is the "NY Statewide Industrial Facilities "Stock Study": Phase Two, Final Report" ("Stock Study") (NYSERDA 2024), supplemented by the U.S. Energy Information Administration's (EIA) Manufacturing End Use Consumption Survey (MECS) and other secondary data.

The study addresses energy savings and decarbonization potential from four categories of industrial technologies:

1. Energy efficiency
2. Electrification
3. Low-carbon fuels, feedstocks, and energy sources (referred to as low-carbon fuels)
4. Carbon capture, utilization, and storage (CCUS)

The study estimates energy and emissions savings relative to the base levels that would exist absent increased adoption of these technologies. The base level in each year reflects changes in manufacturing capacity over the analysis horizon, based on the subsector-level projections in the 2023 Annual Energy

Outlook (EIA 2023), the most recent available at the time of the analysis. The projections do not assume major expansions, such as from the reshoring of manufacturing. Accordingly, the study does not model measures designed for new construction contexts.

S.2 Methodology

The study examines the energy and emissions impact of the four decarbonization categories and reports results for technical and economic potential, and achievable potential under specific adoption scenarios. For each scenario and level of potential, the team calculates annual energy savings and emissions as the sum of savings for new measures implemented that year and rollover savings from measures adopted in prior years.

A "measure" is a particular decarbonization activity or technology investment that creates savings over time relative to the baseline equipment and condition. The team develops measure pairs (baseline activity paired with a decarbonizing measure) and characterizes them by energy and GHG emissions savings, implementation costs, expected useful life (EUL), the proportion of the facility stock to which the measure could apply (feasibility), and current stock penetration of the measure.

When multiple measures can replace the same baseline equipment, they compete against each other based on expected savings, costs, and other factors. This competition occurs in all scenarios. In addition to estimating potential with competition across all measures in all categories, the team also calculated stand-alone technical and economic potential for each of the four measure categories without competition from measures in the other three categories. Appendix A contains a detailed methodology of measure competition.

"Technical potential" represents the upper limit of emissions reduction potential (referred to in total as "decarbonization potential") based on available technologies, matching applications for those technologies, stock turnover, and the market's capacity to deliver the measure.

"Economic potential" refers to the portion of the technical potential that is cost-effective, as determined by the PSC's societal cost test (SCT) established in January 2016 (PSC 2016). The SCT is a benefit-cost analysis (BCA) screen, based on the ratio of the net present value of the measure's societal benefits to the corresponding net present value of the measure's costs, using a societal discount rate. Economic measures are those with an SCT benefit/cost ratio of 1.0 or greater.

The study team produced two estimates of economic potential based on different forecasts for the societal cost of GHG emissions from the New York State Department of Environmental Conservation (DEC):

- **Low Societal Cost of Carbon Scenario**
  Uses the DEC's lowest estimate of the social cost of GHG emissions, developed using a 3% discount rate.
- **High Societal Cost of Carbon Scenario**
  Uses the DEC's central estimate of the social cost of GHG emissions, developed using a 2% discount rate.

"Achievable potential" is the impact of measures adopted under specific scenarios representing real-world factors that can affect customer adoption decisions. These factors include availability and awareness of measures, costs, and savings; energy and carbon (if applicable) prices; market barriers; and program interventions. Table S-1 presents the adoption scenarios examined in this study to explore achievable potential.

Table S-1. Achievable Potential Scenario Descriptions and Assumptions

Key Assumptions	Base	Site Incentive	Carbon Price	Carbon Price+
Renewable natural gas (RNG) price	Base case RNG price forecast from the *New York State Climate Action Council Scoping Plan* (CAC 2022)	Base	Base	Base
Green hydrogen price (NYSERDA 2025)	Hydrogen price forecast (conservative case scenario provided by NYSERDA) that considers IRA production tax credit	Base	Base	Base
Carbon price	No emissions cap or carbon price set	Base	Provided by NYSERDA	Provided by NYSERDA
Incentive levels (starting in model year 2023)	Set to zero. No benefits to improve Internal Rate of Return (IRR)	Incentives bring IRR for each measure to 10%–16%, capped at 70% of the incremental cost	Incentives bring IRR for each measure to 10%–16%, capped at 70% of the incremental cost	Incentives bring IRR for each measure to 10%–16%, capped at 70% of the incremental cost
Program budgets[a]	Annual budget set to zero	Marketing budget: $155,000	Marketing budget: $2,770,000	Marketing budget: $2,770,000 from 2026 onward, increasing with revenue generated from the carbon price

Table S-1. (continued)

Key Assumptions	Base	Site Incentive	Carbon Price	Carbon Price+
Market barriers	Assumptions vary by measure but do not change over time	Base	Base	Base assumptions for Year 1 lowered over time for electrification, low-carbon fuels, and CCUS
Emerging technology cost over time assumption	Cost declines over time for only emerging technologies, reference case trajectory[b]	Base	Base	Base
Emerging technology improved performance assumption	Two emerging tech performance periods: 2025–2034 and 2035–2050, reference case[b]	Base	Base	Base

[a] Marketing budget determines how many customers are aware of a measure and is one factor in determining measure uptake.
[b] Technology cost declines and improved performance assumptions are based on EIA data that offers changes in cost and efficiency trajectories over time for emerging technologies. “Reference case” and “high case” refer to EIA cost scenarios.

The study team also modelled two additional scenarios:

- **Electrification Breakthrough**
  The scenario used the same assumptions as the Carbon Price+ scenario, but included breakthrough electrification technologies for high-temperature process heating, including lime kilns and sinter kilns.
- **Hydrogen Breakthrough**
  The scenario used the same assumptions as in the Carbon Price + scenario, but it used the optimistic (rather than the conservative) hydrogen price forecast from the recently published *New York State Hydrogen Assessment* (NYSERDA 2025).

The results of the breakthrough scenarios did not differ substantially from the Carbon Price+ scenario. The Hydrogen Breakthrough scenario matched the energy savings and emissions reduction potential almost identically. The Electrification Breakthrough scenario increased savings potential by roughly 2%–3% over the Carbon Price+ scenario in the outer years. Because of these similarities, the study team does not discuss the results of these scenarios in detail.

S.3 Key Findings

New York State’s Industrial sector has the technical potential to reduce its energy usage by 21% and GHG emissions by 69% compared to their respective baselines in 2050, and the economic potential to reduce energy usage by 26% and emissions by 40% to 48% (shown in Table S-2).

By savings category, the mix of measures making up economic potential includes more energy efficiency than the mix for technical potential. Technical potential consists of a larger share of measures that are energy neutral (like hydrogen) or increase energy use (like CCUS). This difference results in higher energy savings for economic decarbonization potential (26%) than for technical potential (21%) in 2050. Achievable potential under various scenarios ranges from 16% to 21% energy savings, corresponding to emissions reductions of 21% to 30% compared to the baseline in 2050.

Table S-2. Energy and Emissions Impacts by Scenario

Scenario	2027	2030	2040	2050
Energy savings				
Baseline consumption (million MMBtu)	176	178	186	201
Cumulative savings (million MMBtu)				
Technical potential	20	30	40	41
Economic potential, HiCO_2Value	15	23	40	52
Economic potential, LoCO_2Value	15	23	39	52
Carbon Price+ scenario	8	16	32	42
Carbon Price scenario	7	14	29	37
IRR Incentive scenario	6	12	25	32
Savings as % of baseline				
Technical potential	11%	17%	21%	21%
Economic potential, HiCO_2Value	8%	13%	21%	26%
Economic potential, LoCO_2Value	8%	13%	21%	26%
Carbon Price+ scenario	5%	9%	17%	21%
Carbon Price scenario	4%	8%	15%	19%
IRR Incentive scenario	3%	7%	13%	16%
Emissions reductions				
Baseline emissions (thousand $MTCO_2e$)	18,175	15,981	13,123	13,921
Cumulative savings (thousand $MTCO_2e$)				
Technical potential	2,361	3,531	7,193	9,659
Economic potential, HiCO_2Value	1,545	2,144	3,859	6,730
Economic potential, LoCO_2Value	1,509	2,075	3,466	5,536
Carbon Price+ scenario	753	1,499	3,051	4,208
Carbon Price scenario	706	1,332	2,588	3,381
Site Incentive scenario	532	1,130	2,296	2,890
Savings as % of baseline				
Technical potential	13%	22%	55%	69%
Economic potential, HiCO_2Value	9%	13%	29%	48%
Economic potential, LoCO_2Value	8%	13%	26%	40%
Carbon Price+ scenario	4%	9%	23%	30%
Carbon Price scenario	4%	8%	20%	24%
Site Incentive scenario	3%	7%	17%	21%

S.3.1 Potential by Decarbonization Category

Electrification is the largest source of achievable energy savings potential in New York State's Industrial Manufacturing sector throughout the forecast. Currently, cost-effective electrification opportunities exist for many drying and curing processes, including infrared, induction, microwave, and ultraviolet drying and curing. From 2025 through 2050, a little more than half of the achievable energy savings potential across all adoption scenarios comes from electrification. Energy efficiency makes up the next largest share, accounting for at least 42% and 41% of energy savings potential across all adoption scenarios in 2025 and 2050, respectively.

Electrification is also the largest source of achievable emissions reduction potential in the NYS Industrial Manufacturing sector throughout the forecast. Across adoption scenarios, electrification's importance grows over time, accounting for one-half, two-thirds, and three-quarters of achievable emissions reduction in 2025, 2030, and 2050, respectively. Energy efficiency makes up the next largest share, accounting for at least 45%, 35%, and 18% of decarbonization potential in 2025, 2030, and 2050, respectively, across all adoption scenarios. The impact of electric energy efficiency on emissions declines over time as the electric grid decarbonizes.[2]

Low-carbon fuels do not offer energy savings potential because they are energy neutral. In contrast, low-carbon fuels have the technical potential for emissions savings: about 24% of baseline emissions by 2050 when competing with other measure categories, and about 40% without that competition. These fuels offer modest economic decarbonization potential, at 2.3% of 2050 baseline emissions, and show minimal adoption even under the Carbon Price+ scenario (0.01% of baseline). The low-carbon fuels emissions reduction potential accounts for most of the gap between the technical and economic emissions reduction potential. All low-carbon fuel adopted was green hydrogen, replacing base petroleum use. While renewable natural gas (RNG) had some technical emissions reduction potential, none of it was economic.

CCUS shows negligible or negative energy savings in both technical and economic potential because these measures reduce emissions but require energy to operate CCUS. Similarly, CCUS energy savings potential under the Site Incentive, Carbon Price, and Carbon Price+ adoption scenarios is either zero or negligible. In terms of emissions reduction potential, CCUS shows little to no technical emissions reduction potential early in the forecast, comprising less than 1% of the total by 2027, but increases to 3.2% by 2030, 15% by 2040, and 29% by 2050. This increase in technical potential over the analysis timeframe is partly driven by assumed barrier reductions due to public infrastructure investment.

CCUS also contributes significantly to economic decarbonization potential in 2050 (30%) but has limited achievable potential, with only the Carbon Price+ scenario showing more than negligible CCUS savings. Adoption is limited due to high market barriers related to carbon dioxide (CO_2) storage site availability and transportation. While the Carbon Price+ scenario assumes that public investment in infrastructure will dramatically reduce barriers to CCUS adoption, this process takes time, and adoption of CCUS does not begin until after 2035. By 2050, CCUS contributes modestly to emissions reduction in the Carbon Price+ scenario, making up 6% of potential.

S.3.2 Potential by End Use

The process heating end use accounts for more than half of manufacturing energy use and contributes the most energy savings and emissions potential across all potential levels and adoption scenarios. These savings come primarily from natural gas electrification (80% or more) and efficiency. Heating, ventilation, and air conditioning (HVAC), primarily electrification, is the second-largest source of end-use savings.

When considering heating broadly, including non-process heating, low-temperature process heating measures make up the largest share of energy savings and emissions reductions throughout the forecast under the Carbon Price+ achievable potential scenario. However, medium-temperature heat grows more rapidly and, by 2050, represents 34% of heating emissions reduction potential, compared to low-temperature's 40%. They contribute similar shares of energy savings potential in 2050.

S.3.3 Potential by Subsector

The Chemicals, Food, and other subsectors contributed the most to achievable energy savings. Together, these subsectors account for 53% to 55% of energy savings potential in the adoption scenarios. Chemicals and Food are the two largest contributors, making up 37% to 38% of the total.

The Chemicals, Transportation Equipment, and Food subsectors contribute the most to achievable emissions reduction. Together, they account for 51% to 55% of potential in the adoption scenarios. Subsector potential depends on both baseline emissions and the percent savings achievable. Chemicals has high baseline emissions and middling savings as a percent of baseline, while Transportation Equipment and Food rank in the middle for baseline emissions but have high percent savings (73% and 60%, respectively). In the Carbon Price+ scenario, 24% of the emissions reduction potential in the Chemicals sector comes from CCUS, accounting for almost all the CCUS potential in that scenario.

1 Introduction

The New York State (NYS) Public Service Commission (PSC) directed New York State Energy Research and Development Authority (NYSERDA) to conduct and periodically update a comprehensive statewide potential study encompassing energy efficiency, electrification, and decarbonization. The work is carried out in consultation with the Department of Public Service (DPS) staff and utility representatives (DPS 2020). NYSERDA contracted DNV to assess the potential for energy efficiency, electrification, and decarbonization in the NYS Industrial sector. DNV completed an initial industrial sector potential study in August 2023.

This report documents the findings of an updated statewide Industrial sector potential study (the study), which draws on more robust and comprehensive data. The study relies primarily on the baseline data from the "NY Statewide Industrial Facilities "Stock Study": Phase Two Final Report" (the "Stock Study"), completed in June 2024 (NYSERDA 2024). The "Stock Study" included detailed information gathered through web and phone surveys of more than 600 facilities and on-site visits to more than 100 facilities.

1.1 Objectives

The primary objective of the study is to identify and quantify potential energy savings and greenhouse gas (GHG) emissions reduction opportunities in the NYS Industrial sector. The study considers multiple fuels, including electricity, natural gas, oil, propane, coal, and gasoline, over a 25-year forecast horizon beginning in 2025.

A secondary study objective is to inform the planning and design of decarbonization interventions in the Industrial sector; however, this study does not forecast savings potential for specific program designs. The study focuses exclusively on the NYS Industrial Manufacturing sector and does not include other sectors that could be considered industrial, such as Construction, Agriculture, or Mining. In this report "industrial sector" will refer to the Industrial Manufacturing sector examined for this study.

The study assessed potential savings across four industrial decarbonization categories identified in the U.S. Department of Energy's (DOE) *Industrial Decarbonization Roadmap* (2022):

1. Energy efficiency
2. Electrification

3. Low-carbon fuels, examining renewable natural gas and green hydrogen[3]
4. Carbon capture, utilization, and storage (CCUS)

The study evaluates energy savings and decarbonization potential across all Industrial Manufacturing subsectors, with a particular focus on eight high-energy use and high-emission subsectors, and produces estimates of decarbonization potential per subsector and under several scenarios. For each scenario (see Section 1.2 for descriptions), the study team aggregates results from the subsector-level analysis and produces scenario-specific potential estimates for the Industrial sector.

Energy and emissions savings are estimated relative to a baseline scenario reflecting business as usual conditions, with no incentives to adopt decarbonization technologies. This baseline in each year reflects expected changes in manufacturing capacity over time, based on the subsector-level projections in the *2023 Annual Energy Outlook* (EIA 2023), the most recent available at the time of the analysis. The projections do not assume major expansions such as reshoring of manufacturing and do not include measures designed for new construction.

1.2 Levels of Savings Potential and Scenarios

The study estimates three levels of potential

1. **Technical Potential**
   Represents the maximum possible GHG emissions reduction potential (also referred to as decarbonization potential, emissions reduction potential, or emissions savings) based on available technologies and measures that the facilities can take, without regard to cost. This study maximizes decarbonization potential and then examines the associated energy savings or peak demand potential reduction. Measure implementation each year depends on the remaining feasible stock where the measure is not yet applied—that is, on the feasibility and on the not-complete factor, where the latter equals one minus the current stock penetration of the measure. As measures are implemented each year, the remaining stock for additional measure implementation (the not-complete factor) reduces.[4]
2. **Economic Potential**
   Refers to the technical potential that is cost-effective. The study determines cost-effectiveness using the benefit-cost analysis (BCA) framework, which the PSC established in January 2016 (PSC 2016). The BCA framework uses the societal cost test (SCT), which calculates the outcome as the ratio of net present value for the measure's societal benefits and costs, using a societal discount rate. Economic measures have an SCT benefit/cost ratio of 1.0 or greater. Each year's implementation depends on the societal benefit/cost ratio, which in turn depends on the measure life together with annual measure costs, carbon costs, and energy costs. These costs vary over the time frame of the analysis.

3. **Achievable Potential**
   Is the savings potential under specific scenarios representing real-world factors that can affect customer adoption decisions. These factors include decarbonization measure availability, costs, and savings; carbon and energy (if applicable) prices; market barriers; and program interventions. Achievable potential depends on the benefit/cost ratio from the customer perspective. For a given benefit/cost ratio, higher market barriers reduce adoption.

For each scenario and level of potential, the study calculated energy and carbon savings annually as the sum of savings for measures implemented that year. A "measure" is a particular decarbonization activity or technology investment that creates savings over time, depending on the baseline equipment/condition. The study then developed measure pairs, matching existing industrial activity in the State with energy- or carbon-saving measures, and characterizes them in terms of the resulting annual savings, implementation costs, expected useful life, proportion of the facility stock the measure could apply to (feasibility), and current stock penetration of the measure. Lastly, the study calculated cumulative savings based on each annual savings level and rollover savings from measures implemented in prior years.

1.2.1 Technical and Economic Potential

Technical potential assesses the savings if customers adopt all feasible[5] decarbonization measures, subject to stock turnover and maximum annual adoption rates that represent the market's capacity to deliver each measure, but ignoring any other market barriers and the cost of the measure. The technical potential assumed that public investment would add infrastructure that expanded the market capacity for certain technologies, especially low-carbon fuels, CCUS, and electrification. When existing equipment reaches the end of its lifecycle, customers replace their equipment with the lowest-emitting option available. Customers install retrofit measures at the maximum feasible rate the market can support. The technical and economic potentials focus on what technologies deliver the maximum savings, and the results should not be viewed as a prediction for the level of deployable green hydrogen, renewable natural gas (RNG), or CCUS. Appendix A provides a detailed description of the technical potential analysis. This case is primarily for planning and informational purposes.

Economic potential represents a subset of technical potential measures with a societal benefit/cost ratio of 1.0 or greater. Section 4 and Appendix A include descriptions of the benefits and cost elements. The study team produced two estimates of economic potential based on different forecasts for the societal cost of GHG emissions from the New York State Department of Environmental Conservation (DEC 2025). The DEC's forecasts differ in the discount rate applied to the future impacts of GHGs. The two economic potential scenarios are:

- **Low Societal Cost of Carbon Scenario**
  This scenario used the DEC's lowest estimate of the societal cost of GHG emissions, developed using a 3% discount rate.
- **High Societal Cost of Carbon Scenario**
  This scenario used an alternative forecast for the societal cost of GHG emissions that is higher than the forecast used in the low case (developed using a 2% discount rate, which the DEC characterizes as its central rate).

A higher avoided cost of GHG emissions increases the societal benefits of carbon-saving measures, resulting in more measures passing the economic screening in the higher societal cost of carbon scenario and higher economic potential. Because adoption modelling is based on consumer factors, not the SCT, these carbon values do not impact adoption scenarios and are only used to calculate economic potential.

1.2.2 Achievable Potential Scenarios

Achievable potential is expressed through the development of illustrative adoption scenarios that reflect possible futures with different market or policy conditions. These scenarios analyze the potential for the adoption of measures given facility owner motivations and constraints, such as cost considerations, customer awareness, equipment replacement cycles, supply chain, workforce barriers, and the extent to which government programs overcome such barriers and constraints. Technical potential, economic potential, and the Carbon Price+ scenario all assume a future where large infrastructure investments reduce barriers to adoption for CCUS, low-carbon fuels, and electrification. This could take the form of public funding for carbon dioxide (CO_2) and hydrogen pipelines, reducing legal and permitting barriers for pipelines and CO_2 storage, and informational and technical assistance.

This study determined achievable potential as a subset of technical potential; it does not require that measures pass a societal benefit/cost screen (as applied to estimate economic potential) to be included in achievable potential estimates. Depending on the scenario to be modelled, the study team adjusted the trajectory of certain inputs, including fuel prices, energy, and demand cost savings, emissions costs, measure awareness, or reducing the share of the measure cost paid by customers through incentives. Table 1 lists the adoption scenarios to explore achievable potential.

Table 1. Achievable Potential Scenario Descriptions and Assumptions

Key Assumptions	Base	Site Incentive	Carbon Price	Carbon Price+
RNG price	Base case RNG price forecast from the *New York State Climate Action Council Scoping Plan* (CAC 2022)	Base	Base	Base
Green hydrogen price	Hydrogen price forecast (conservative case scenario provided by NYSERDA)[a] that considers IRA production tax credit	Base	Base	Base
Carbon price	No emissions cap or carbon price set	Base	Provided by NYSERDA	Provided by NYSERDA
Incentive levels (beginning in model year 2023)	Set to zero	Incentives bring IRR[b, c] for each measure to 10%–16%, capped at 70% of incremental cost	Incentives bring IRR[b, c] for each measure to 10%–16%, capped at 70% of incremental cost	Incentives bring IRR[b, c] for each measure to 10%–16%, capped at 70% of incremental cost
Program budgets[c]	Set to zero	Marketing budget: $155,000	Marketing budget: $2,770,000	Marketing budget: $2,770,000, which increases with revenue generated from the carbon price
Market barriers	Assumptions vary by measure but do not change over time	Base	Base	Base assumptions for Year 1 lowered over time for electrification, low-carbon fuels, and CCUS
Emerging technology cost over time assumption	Cost declines over time for only emerging technologies, reference case trajectory[b]	Base	Base	Base
Emerging technology improved performance assumption	Two emerging tech performance periods: 2025–2034 and 2035–2050, reference case[d]	Base	Base	Base
Added breakthrough technologies	No added breakthrough technologies	Base	Base	Base

[a] NYSERDA's team provided hydrogen price forecasts while developing the April 2025 "New York State Hydrogen Assessment," prior to finalizing that document. The study used values consistent with the conservative assumptions underlying the *Base*, *Site Incentive*, *Carbon Price*, and *Carbon Price+* scenarios in this analysis.
[b] Refer to the Glossary for an explanation of IRR.
[c] The marketing budget determines how many customers become aware of a measure and is one factor in determining measure uptake.
[d] The study is based on assumptions for technology cost declines and improved technology performance on EIA data, which presents changes in cost and efficiency trajectories over time for emerging technologies. The "reference case" and "high case" refer to EIA cost scenarios. The study used the high case for breakthrough scenarios (see discussion of those scenarios following this table).

The study team also modelled two additional scenarios:

- **Electrification Breakthrough**
  The scenario used the same assumptions as the Carbon Price+ scenario, but included

breakthrough electrification technologies for high-temperature process heating, including lime kilns and sinter kilns.

- **Hydrogen Breakthrough**
  The scenario used the same assumptions as in the Carbon Price+ scenario, but it used the optimistic (rather than the conservative) hydrogen forecast from the recently published "New York State Hydrogen Assessment, Final Report" (NYSERDA 2025).

The study team also conducted fuel price sensitivities to assess how changes in fuel prices would impact the potential.

1.2.3 Study Assumptions and Limitations

This study incorporates information from a wide range of sources and provides granular annual estimates. The study team has taken steps to ensure that the assumptions and results are realistic and consistent with existing information. At the same time, uncertainty remains regarding many details of current and future market conditions and policies, as well as how decision-makers will respond to them. The study's limitations include the following:

1. This study used fuel price projections from the "Appendix G: Integration Analysis Technical Supplement, New York State Climate Action Council Scoping Plan" (NYSERDA 2022). The study team did not conduct dynamic economic modelling that feeds back adoption levels of low-carbon fuels to supply-side prices. This particularly impacts the cost-effectiveness of low-carbon fuels, both from societal and customer standpoints.
2. Similarly, the study does not use explicit modelling of the effects of specific investments aimed at reducing particular market barriers or the resulting changes in adoption. Rather, the study applied generic adoption curve shapes and reflected investments in barrier reductions by moving to a curve with higher adoption rates.
3. The modelling identified the energy consumption associated with individual end uses for each subsector, the decarbonization measures applicable to each end use, and the adoption levels of those measures. Eight percent of nonfeedstock industrial energy use has no identified end use in the "Stock Study". For this portion, the study identified mostly generic applicable measures, such as strategic energy management and control systems. As a result, the study projected limited savings for this unidentified component. Actual savings opportunities for this component are likely greater.
4. The study explicitly modelled more than 435 individual decarbonization measures applicable to industrial end uses. The team defined each measure's characteristics based on the best available sources and aligned them with typical cases. Prices, impacts, applicability, and availability may vary for individual facilities. While the modelling reflects that different facilities will respond differently to the same set of costs and benefits, and varies these inputs by industrial subsector and size tier, it does not incorporate any assumed distribution of measure costs and benefits.

2 New York State's Industrial Sector

This study examines New York State's Industrial Manufacturing sector, focusing on the top eight subsectors by energy consumption, along with an aggregated category labeled Other Manufacturing. The study is based on 2023 energy consumption and GHG emissions, representing existing industrial facilities across the State.

Data presented in Tables 2 and 3 provide a 2023 snapshot of industrial energy consumption and emissions. These numbers were developed using results from the recently completed "Stock Study". GHG emissions are calculated in alignment with the Climate Leadership and Community Protection Act (Climate Act), including the use of a 20-year global warming potential and the inclusion of out-of-state emissions related to imported fossil fuels.

Table 2. New York Industrial Sector Energy Consumption and Emissions, 2023

Includes fuel and nonfuel.

Source: "Stock Study".

Emissions Type	Energy (million MMBtu)	Emissions (thousand $MtCO_2e$)
Fuel	148.7	16,115
Identified Feedstock and Process[a]	18.8	2,155
Total	**167.6**	**18,270**

[a] Identified feedstock usage from the "Stock Study" process data is estimated at 18.8 trillion Btu, primarily in the Chemicals and Other subsectors. This is out of a total of 168 trillion Btu of industrial energy consumption. Additional feedstock use likely exists in the Manufacturing sector, but was not identified or quantified through the "Stock Study".

Table 3. Energy Consumption and Emissions by Subsector, 2023

Excludes feedstock and process.

Source: "Stock Study".

Subsector	Energy (million MMBtu)	Emissions (thousand $MtCO_2e$)
Paper	30.2	3,224
Chemicals	25.4	2,631
Primary Metals	15.5	1,818
Food	14.4	1,504
Fabricated Metals	14.2	1,590
Transportation Equipment	12.0	1,200
Non-Metallic Minerals	7.5	839
Computer and Electronics	7.2	841
Other	22.4	2,469
Total	**148.7**	**16,115**

Table 4 breaks down the estimated number of manufacturing facilities by subsector and by energy expenditure tier. New York State is home to an estimated 7,777 manufacturing facilities. Almost 96% of these facilities are small facilities (Tier 3), with annual energy expenditures of less than $500,000. Among all subsectors, Fabricated Metals, Food, and Computer and Electronic are the three manufacturing subsectors with the most facilities. The manufacturing subsectors with the largest number of large facilities (Tier 1 and Tier 2) are Food, Paper, Chemicals, Primary Metals, and Non-Metallic Mineral Products. Nearly half of Paper facilities fall into either Tier 1 or Tier 2.

Table 4. New York State Manufacturing Facilities by Subsector, Tier, and Energy Usage

Source: "Stock Study".

NAICS and subsector manufacturing type	Facilities (#)	% of total facilities	Facilities per energy expenditure Tier 1[a]	Facilities per energy expenditure Tier 2[a]	Facilities per energy expenditure Tier 3[a]	Overall energy usage (million MMBtu)
Key subsectors for this study						
332, Fabricated Metal Products	1,570	20%	6	14	1,549	14.2
311, Food	357	5%	[b]	[b]	300	14.4
334, Computer and Electronic Products	196	3%	8	0	188	~7.2[c]
327, Nonmetallic Mineral Products	155	2%	[b]	[b]	130	7.5
325, Chemicals	142	2%	[b]	[b]	106	25.4
322, Paper	90	1%	32	11	47	30.2
336, Transportation Equipment	89	1%	10	11	68	~12
331, Primary Metals	74	1%	15	11	48	~15.5
Nonkey subsectors for this study						
324, Petroleum and Coal Products	21	0%	[b]	0	[b]	500,542
Nonkey subsectors for the "Stock Study"	5083	65%	27	47	5,009	21,884,521
Total	**7,777**	**100%**	**172**	**142**	**7,463**	**148,733,079**

[a] Tier 1: $1,000,000 and above; Tier 2: $500,001–$999,999; Tier 3: less than $500,000
[b] Not enough information available.
[c] The ~ symbol indicates results heavily influenced by one response or high relative standard error (50% and 100%).

While Phase One of the "Stock Study" estimated a substantial number of Petroleum manufacturing facilities in New York State, Phase Two found that most of them were not actual manufacturing facilities. The Petroleum subsector (e.g., asphalt shingles, pavement) represents a small share of New York State's manufacturing facilities and energy use. As a result, while the Phase One Potential Study broke out the Petroleum subsector, the study team included it under Other Manufacturing for this study.

2.1 Energy Usage

Figure 1 depicts overall energy use by subsector. The eight chosen subsectors (Paper, Primary Metals, Non-Metallic Minerals, Chemicals, Food, Fabricated Metals, Transportation Equipment, and Computer and Electronics) account for 85% of total emissions. The ninth subsector combines all remaining subsectors. The eight subsectors align with the “Stock Study”, while the combined subsector includes nonkey subsectors and Petroleum.

Industrial manufacturing facilities in New York State are estimated to consume 149 trillion Btu of energy overall, excluding feedstock use. The Paper subsector accounts for the largest nonfeedstock consumption at 20%, followed by Chemicals, Primary Metals, and Food.

This report includes decarbonization measures that reduce feedstock consumption of fossil fuels, for example, such as their use in producing organic chemicals, plastics, or products like asphalt shingles. The “Stock Study” process data identifies an estimated 18.8 trillion Btu of feedstock usage, primarily in the Chemicals and Other subsectors, contributing to a total of 168 trillion Btu of industrial energy consumption. The Manufacturing sector uses additional feedstock that the “Stock Study” did not identify or quantify.

Figure 1 shows the breakdown of New York State nonfeedstock industrial energy use by fuel type for each subsector. The fuel mix varies by subsector, but natural gas and electricity together dominate all subsectors except Paper. Natural gas represents 43% of total nonfeedstock industrial energy consumption by fuel type, with an estimate of 65 trillion Btu, followed by net electricity (34% of total, or about 51 trillion Btu). HGL stands for hydrocarbon gas liquids, including propane, and represents a small amount of fuel use in manufacturing facilities. The Biomass/Other Fuels category represents nonelectric fuel types such as net steam consumption, woody biomass, and a variety of waste materials and byproducts. As indicated in Figure 1 shows that Paper uses the largest share of this fuel category. Chemicals, Primary Metals, and Other account for most of the remainder. Biomass/Other Fuels account for 19% of total nonfeedstock industrial energy consumption, with an estimate of 28 trillion Btu. Figure 2 shows that Biomass/Other Fuels accounts for 13% of the total process heating and boiler energy consumption (19.5 trillion Btu). The remaining 8.5 trillion Btu of Biomass/Other Fuels consumption does not correspond to a specific end use and therefore falls under End Use Not Reported.

Figure 1. Nonfeedstock Industrial Energy Consumption by Fuel, 2023

Source: "Stock Study".

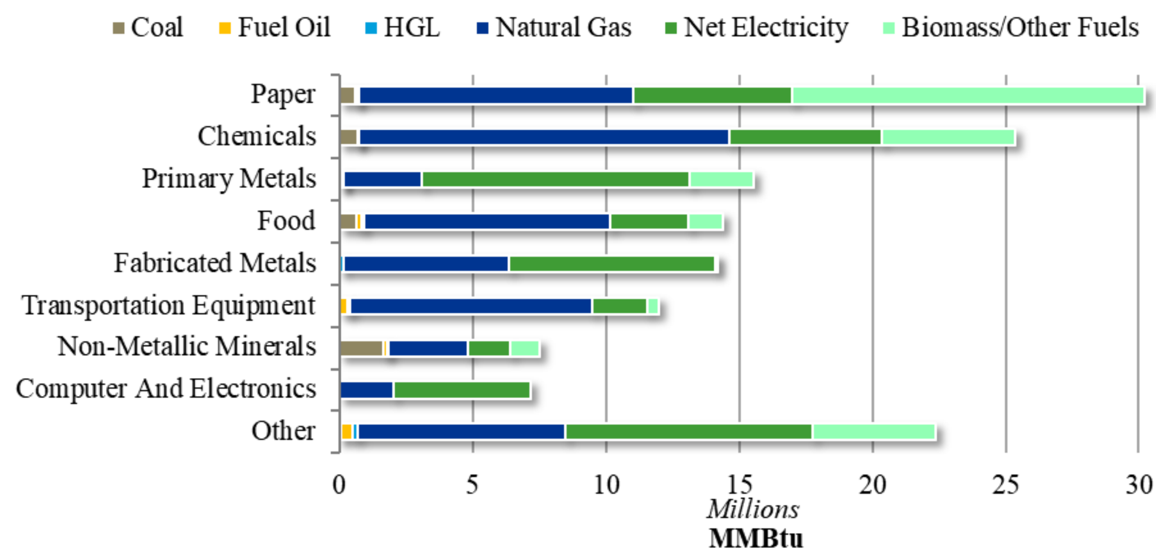
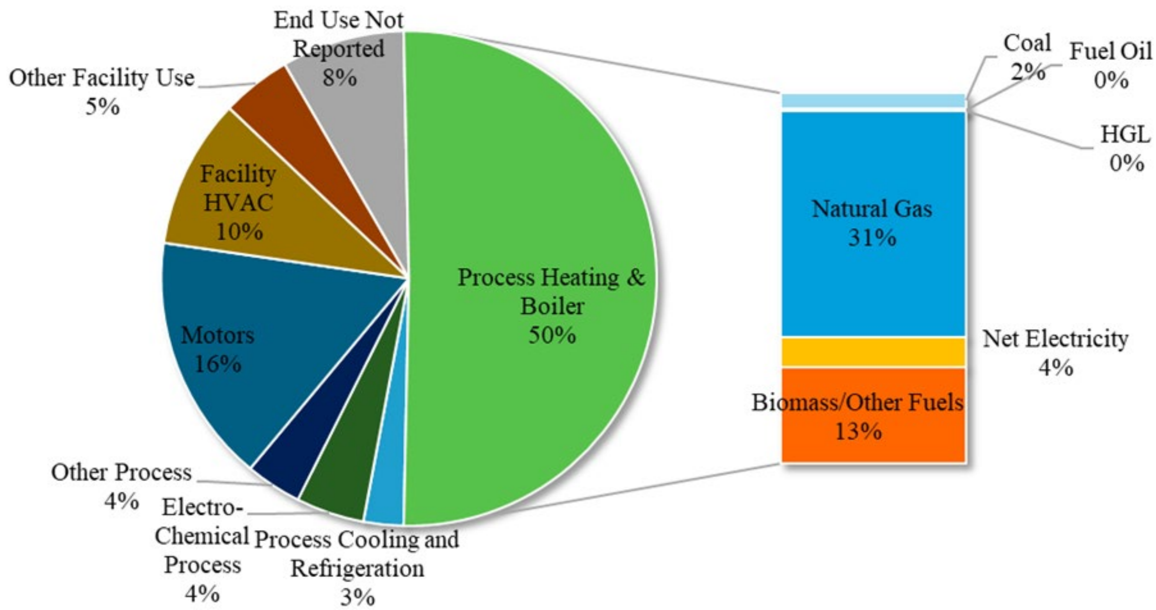


Figure 2 displays the breakdown by end use. Process heating, boilers, and machine drive (motors) are the largest individual end uses, together accounting for two-thirds of usage.

Figure 2. Nonfeedstock Industrial Energy Consumption by End Use, 2023

Source: "Stock Study".



Eight percent of nonfeedstock energy use lacks identified end uses in the data source used for the analysis (see Section 4.3 for more detail). The "Stock Study" surveys collected end-use decompositions for all fuels with the greatest consumption at each facility in the survey sample. This study incorporates those results, which more clearly identify opportunities within this End Use Not Reported category. These results allowed the study team to assign some of Paper's biomass consumption to process heating base equipment and identify energy-efficiency savings for that portion of energy use. This improved resolution into fuel and end uses also enabled CCUS as a way to address emissions from biomass consumption.

The data is rooted in the "Stock Study" surveys, which collected end-use decompositions for the fuels with the greatest consumption at each sampled facility. The surveys estimated fuel type decompositions by subsector and end-use decompositions for electric and nonelectric fuel types, as shown in Figure 1 and Figure 2, but did not provide an end-use breakdown by specific nonelectric fuel types. The study team estimated end-use decompositions for individual nonelectric fuel types using end-use breakdowns for nonelectric fuels and the subsector-level breakdowns of energy consumption by fuel type, then, if necessary, made additional adjustments by consulting MECS survey data by fuel and end use (EIA 2018).

Other fuel types without reported end-use breakdowns include net steam consumption and various waste materials and byproducts. Figure 1 shows that Paper uses the largest share of these fuels. Chemicals, Primary Metals, and Other account for most of the remainder.

Even beyond what the study analyzed for Paper, many of these energy uses are likely addressable by measures included in this study. However, without more detail on the fuel types or end uses, the study team could not assign specific measures nor estimate their adoption levels for the full scope of other fuel consumption. This study addresses the End Use Not Reported component with cross-cutting measures such as strategic energy management, but not with more specific energy-efficiency or electrification measures. Some of this energy use could be addressed with additional measures, including electrification. Hence, the study likely understates the savings potential for this category. However, when facilities use waste and byproduct fuels that are essentially free, the facility economics of decarbonization measures differ from the economics of measures applied to (mostly purchased) primary fuel types directly addressed in this study.

2.2 Emissions

In 2023, emissions from the Manufacturing sector's energy consumption totaled 16,000 $MTCO_2e$. Figure 3 shows how emissions from energy sources used as fuel in NYS industrial facilities break down by fuel type, subsector, and end use. Natural gas and electricity contribute similar amounts, together accounting for about 80% of total emissions. The Paper subsector emits the most, 20% of the total, followed by Chemicals, Primary Metals, and Fabricated Metals.

Figure 3. Nonfeedstock Industrial Energy Emissions by Fuel and Subsector, 2023

Source: "Stock Study".

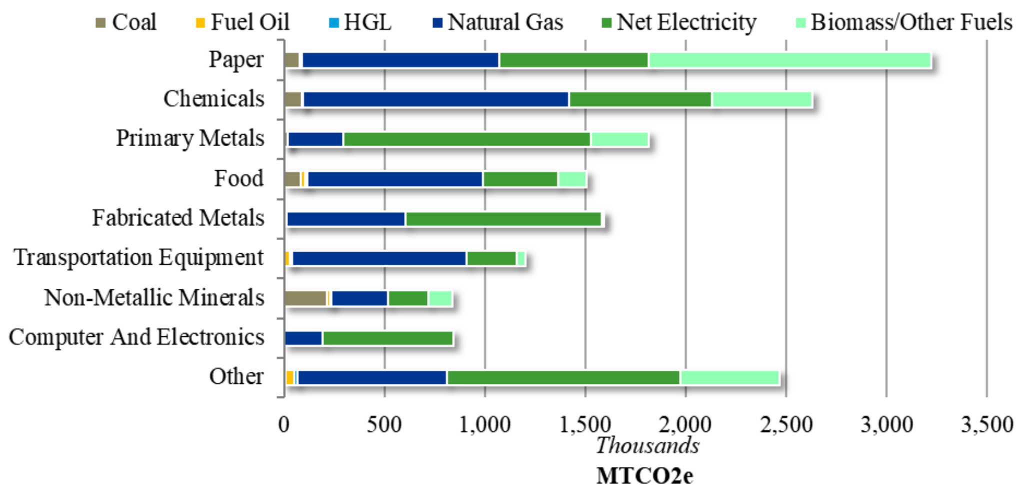
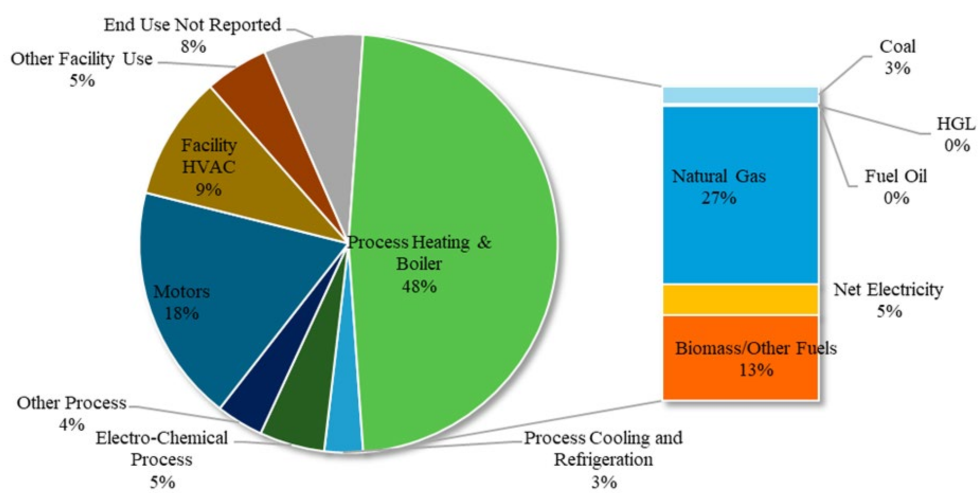


Figure 4 shows the industrial emissions breakdown by end use. As with energy use, process heating, boilers, and machine drive (motors) are the largest individual end uses, together accounting for 66% of emissions.

Figure 4. Nonfeedstock Industrial Emissions by End Use, 2023

Source: "Stock Study".

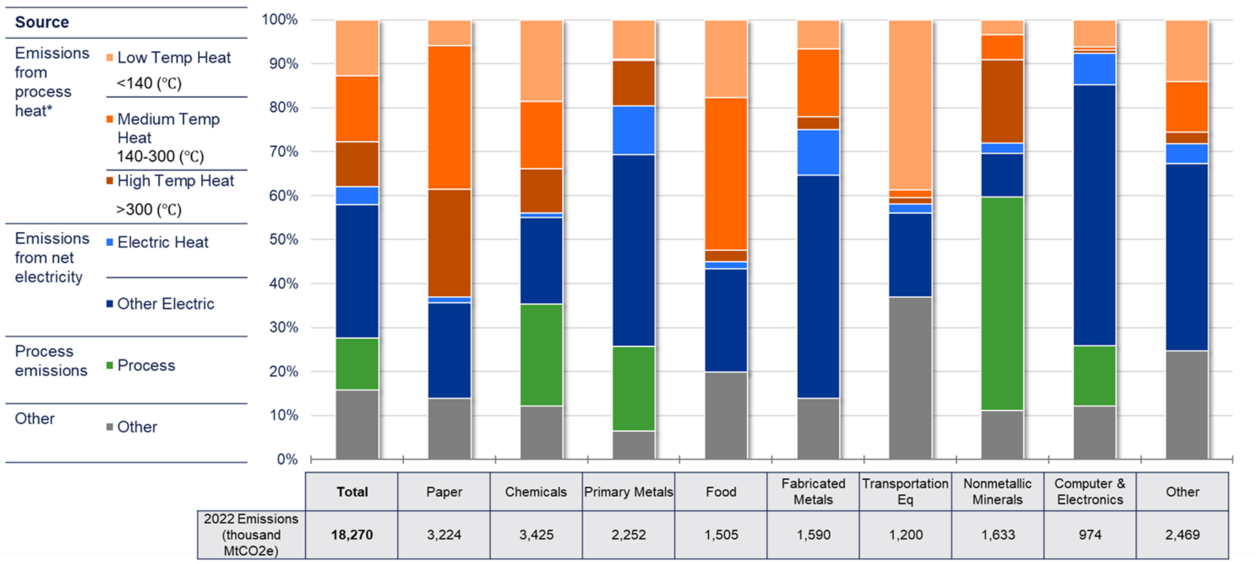


The study team identified about 2,000 $MTCO_2e$ of nonenergy-related emissions from processes and feedstock consumption related to the industrial sector's energy consumption in 2023.

Figure 5 shows how emissions from fuel, feedstock, and processes break down by subsector and source.

Figure 5. Carbon Emissions Breakdown by Source, 2022

Figures as a percent of subsector total. Emissions from process heat include process heating and boiler end uses. Baseline emissions by subsector include energy and applicable nonfuel sources (feedstock use and process-related emissions).



3 Energy and Emissions Savings Potential Findings and Conclusions

This section summarizes and examines the estimated statewide savings potential in the Industrial Manufacturing sector for various levels of potential and adoption scenarios. It provides estimates over time by decarbonization category, by end use, and by New York Independent System Operator (NYISO) zone. Appendix B includes tables of estimates by facility size Tier, NYISO zone, and disadvantaged community (DAC) status.

All results in this section account for competition between measures. Multiple decarbonization categories, energy efficiency, electrification, low-carbon fuels, and CCUS, may address the same base emissions. Some measures complement each other; for example, many energy efficiency measures apply to low-carbon and base fuels. Others compete, such as electrification and low-carbon fuels. The industrial decarbonization model used for this study (the model) incorporates an approach to competition, described in Appendix A. To view the potential for each decarbonization category without competition from other categories, see Appendix A for stand-alone technical and economic decarbonization estimates.

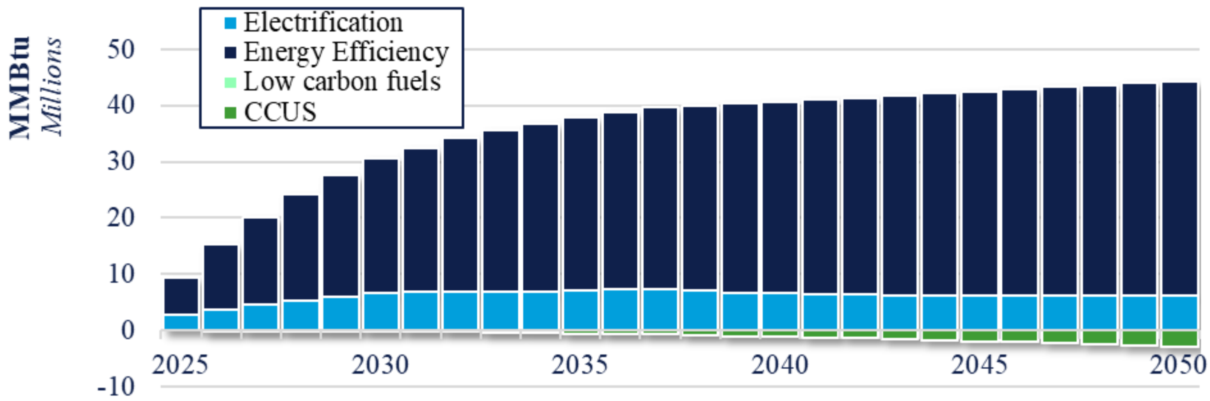
3.1 Technical and Economic Savings

This section introduces the study's levels of potential and decarbonization scenarios, outlining the assumptions and mechanisms used to estimate emissions and energy savings, as well as findings for each.

3.1.1 Technical Potential

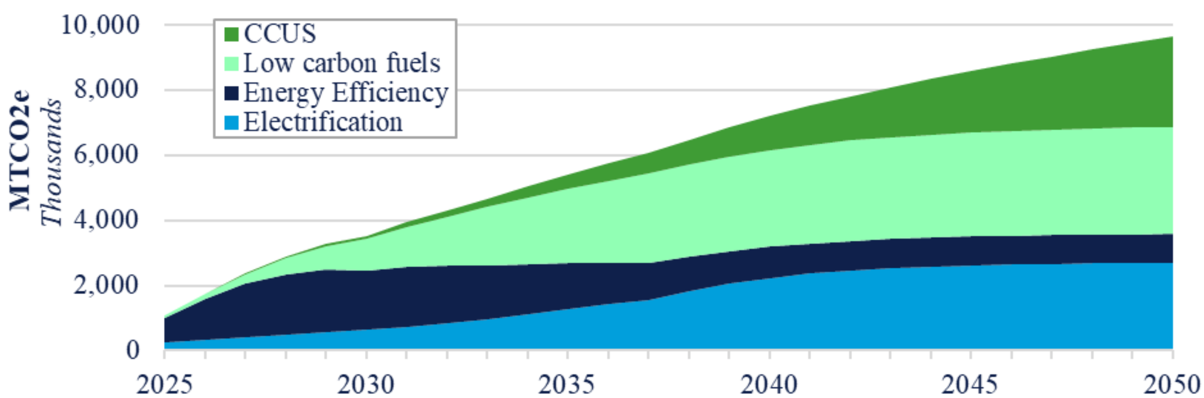
By 2050, New York State's technical potential energy savings reach 41 trillion Btu or 21% of baseline 2050 consumption (Figure 6). Low-carbon fuels do not contribute to energy savings because they are energy neutral; reductions in fossil fuels are offset by equivalent MMBtu of the low-carbon fuel. CCUS appears as a negative energy savings value because it reduces emissions but requires energy to operate.

Figure 6. Technical Potential Energy Savings by Category, 2050



Decarbonizing electricity generation creates very different patterns for decarbonization potential (Figure 7) compared to the energy savings potential. While energy savings potential increases over time, energy efficiency's decarbonization potential decreases. Although the potential for electric energy efficiency will likely continue to help manage electricity load, its emissions benefits will decline over time.

Figure 7. Technical Potential Emissions Savings by Category, 2025–2050



By 2050, technical decarbonization potential in New York State's Industrial Manufacturing sector reaches 9.7 million $MTCO_2e$, or 69% of estimated baseline 2050 emissions. As Figure 7 shows, energy efficiency measures dominate early technical potential for decarbonization. In later years, low-carbon fuels, specifically green hydrogen, become the largest contributor (3.3 million $MTCO_2e$ by 2050), followed by CCUS (2.8 million) and electrification (2.7 million). By 2050, energy efficiency accounts for only 9.1% of technical emissions reduction potential. Decarbonizing New York State's electric grid[6] reduces the emissions impacts of electric energy efficiency measures over time, leading to declining emissions reductions. At the same time, grid decarbonization of the electric grid increases the emissions benefits from electrification.

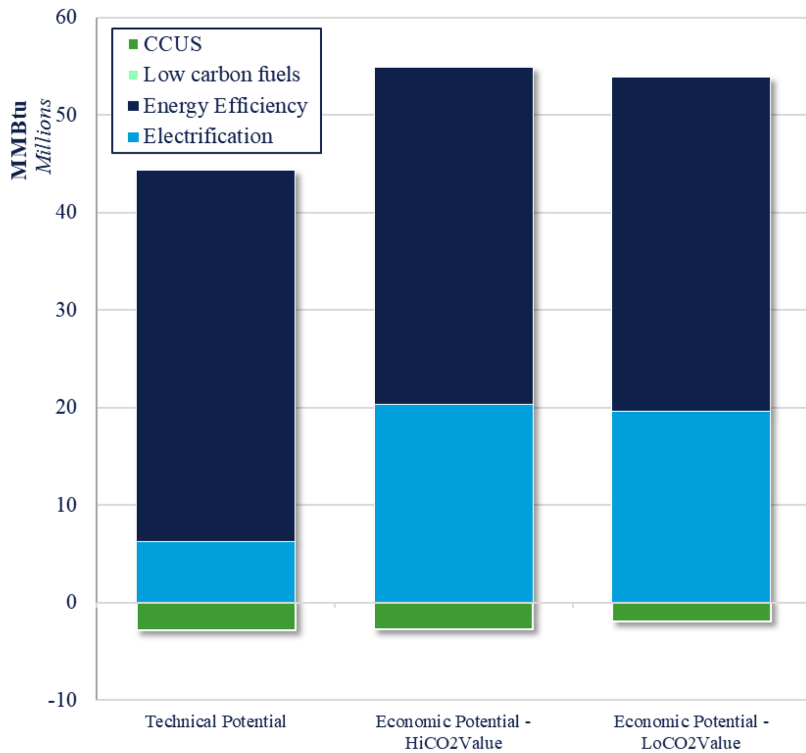
These levels of low-carbon fuels (specifically green hydrogen) and CCUS potential reflect the mix of technologies that maximize decarbonization. However, technical potential does not reflect supply or infrastructure limitations in these developing markets and should not be interpreted as a prediction of deployable low-carbon fuels or CCUS.

3.1.2 Economic Potential

The study developed two economic potential estimates using alternative societal cost of CO_2 forecasts described in Section 1.2.1. Both forecasts are from DEC, but they use different discount rates to estimate the future impacts of GHGs: the low societal cost of carbon scenario uses a 3% discount rate, and the high societal cost of carbon scenario uses a 2% discount rate.

Figure 8 compares the two economic energy savings potential estimates with the technical potential in 2050. Counterintuitively, economic potential exceeds technical potential by more than 25% in both CO_2 value scenarios. This occurs because the model optimizes for emissions reduction potential, and many emissions-reduction measures either do not save energy or increase energy use. The reported technical and economic energy savings reflect energy savings associated with the technical and economic emissions reduction potential, not the total energy savings potential that a model optimizing for energy savings would produce. The technical emissions reduction potential includes significant savings from low-carbon fuels, which are energy neutral. This inclusion increases total emissions reductions but reduces energy-efficiency savings, which typically lose in competition with low-carbon fuels due to their lower emissions savings rates. When calculating economic emissions reduction potential, by contrast, the model finds few low-carbon fuel measures to be cost-effective, while many energy-efficiency measures are. With less competition, more of the economic emissions reduction comes from energy efficiency, which contributes to the associated energy savings potential, whereas low-carbon fuels do not.

Figure 8. Technical and Economic Energy Savings Potential, 2050



Energy efficiency, by definition, saves energy. In the economic potential analysis, it contributes about two-thirds of energy savings; in the technical potential analysis, it contributes more than 90%. Electrification contributes 38% to 39% of energy savings for economic potential, depending on the value of carbon, but only 15% in technical potential. CCUS results in negative energy savings, and low-carbon fuels do not reduce overall energy use. In the economic analysis, energy savings reach 52 million MMBtu by 2050 in the Low Carbon Dioxide Value (LoCO_2Value) scenario, or 26% of baseline energy consumption. Between the two CO_2 value cases, the high-value case energy savings are less than 1% higher than the low-value case in 2050.

Figure 9. Economic Potential for Energy Savings, Low Carbon Dioxide Value

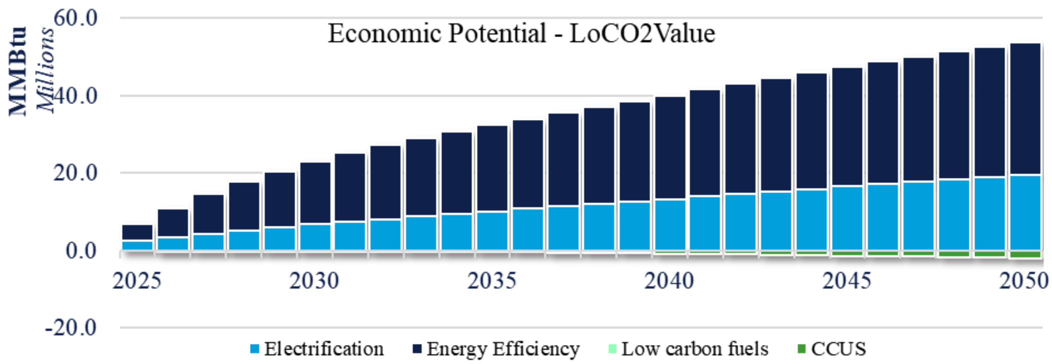


Figure 10. Economic Potential for Energy Savings, High Carbon Dioxide Value

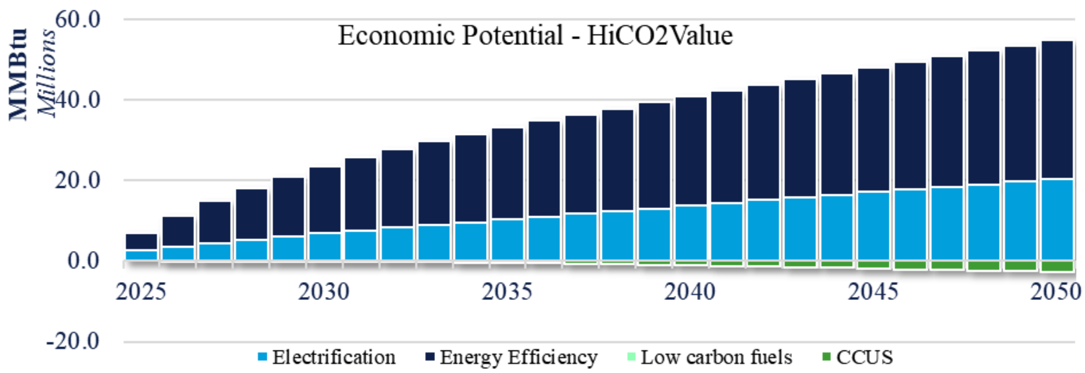
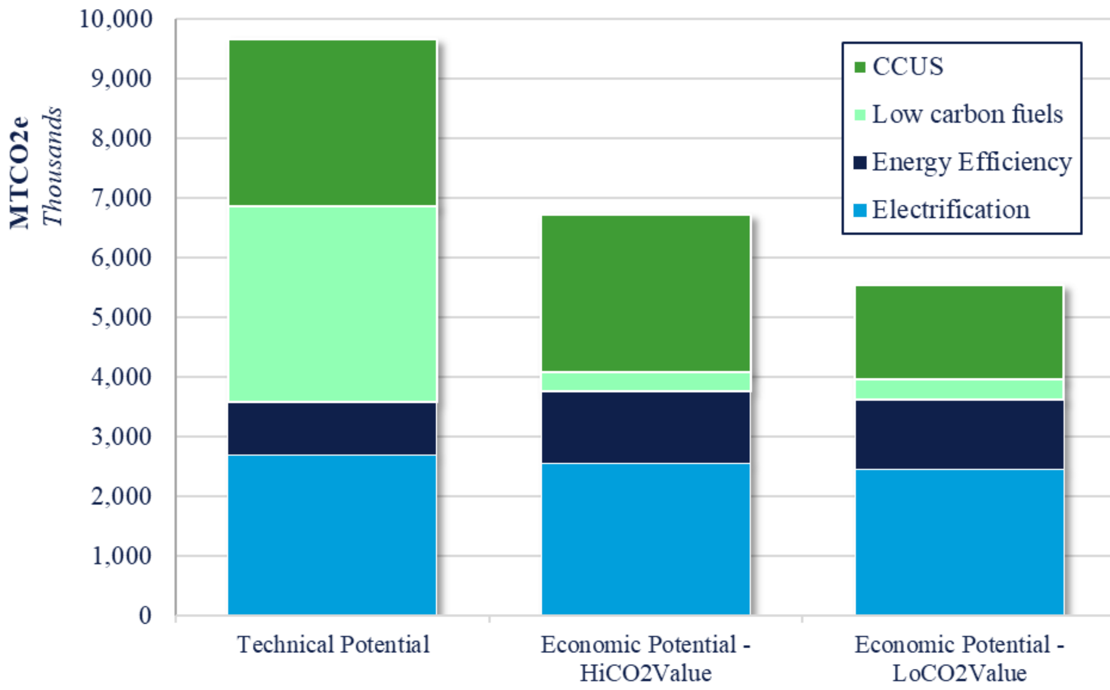


Figure 11 compares economic decarbonization potential with technical potential in 2050. Under the Low CO_2 Value scenario, economic potential reaches 57% of technical potential emissions in 2050 (39% of base emissions). Under the High CO_2 Value (HiCO_2Value), it climbs to almost 70% of technical potential in 2050 (48% of base), primarily due to more cost-effective CCUS savings. Under the HiCO_2Value, 94% of CCUS technical potential is economic.

Figure 11. Technical and Economic Emissions Reduction or Decarbonization Potential, 2050



While the overall economic decarbonization potential is lower than technical potential, it does not always remain lower at the category level. Because measures compete for the same opportunities, economic potential for energy efficiency exceeds technical energy efficiency potential after 2039. In the technical potential calculation, low-carbon fuel and CCUS measures that have large technical decarbonization potential but fail the societal cost test (SCT) still beat out cost-effective energy efficiency measures with lower technical potential. In the economic potential calculation, the model only allows measures that pass the SCT to compete. This removes most of the low-carbon fuels measures and many CCUS measures from competition, allowing energy efficiency to capture a greater share of total economic potential than in technical potential.

Figure 12 and Figure 13 show economic decarbonization potential by category over time for the LoCO_2Value and HiCO_2Value cases. Early in the forecast, energy efficiency dominates, representing as much as 71% in 2027. Energy efficiency that addresses electricity consumption sees declining emissions benefits over time as electricity generation decarbonizes. Because this type of efficiency makes up a large share of modelled energy efficiency, its emissions benefits decline until the grid fully decarbonizes in

2040. After that, growth remains low due to energy efficiency targeting other fuels. By 2050, energy efficiency represents only 21% of decarbonization potential in the LoCO_2Value case, compared to 44% for electrification, 6% for low-carbon fuels, and 29% for CCUS. In the HiCO_2Value case, energy efficiency represents only 18%, electrification 38%, low-carbon fuels 5%, and CCUS 39%.

Figure 12. Economic Decarbonization Potential, Low Carbon Dioxide Value Case

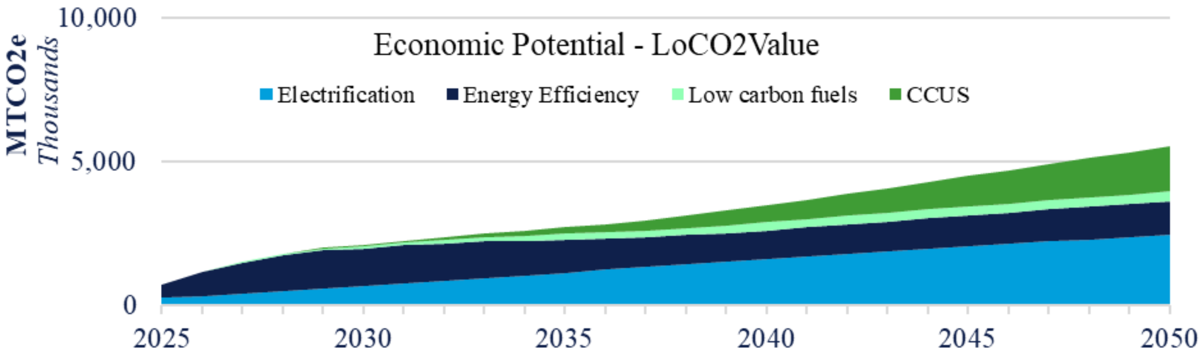


Figure 13. Economic Decarbonization Potential, High carbon Dioxide Value Case

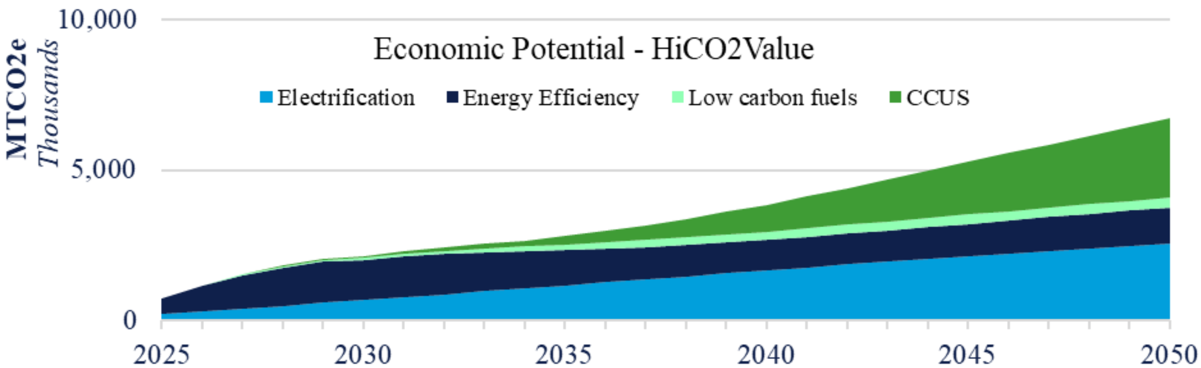
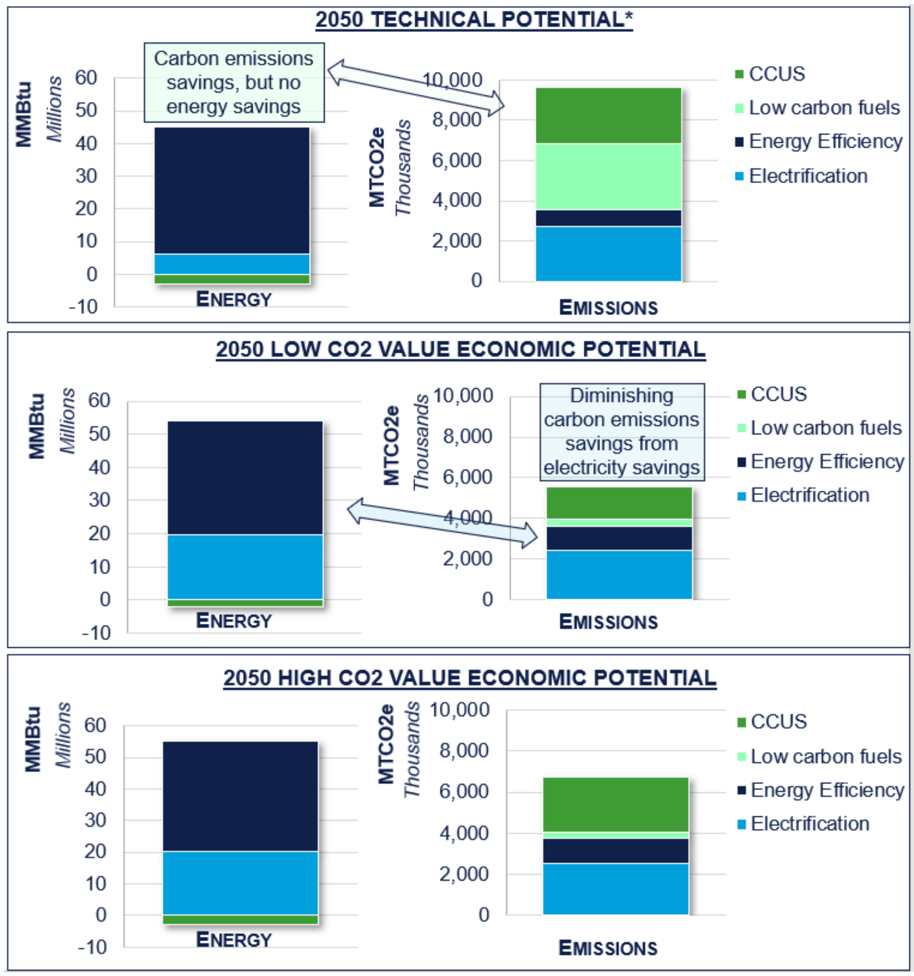


Figure 14 summarizes the technical and economic potential estimated for 2050 for both energy and emissions. The figure allows comparisons between the energy savings and emissions reduction potential based on the dominant savings categories.

Figure 14. Energy and Emissions Savings Corresponding to Technical and Economic Potential, 2050

CCUS energy impacts are negative.



3.2 Adoption

Achievable decarbonization potential varies across adoption scenarios in both magnitude and the shares by category, end use, subsector, and NYISO zone. However, energy savings patterns are more consistent across the various lenses used in this analysis.

Figure 15 and Figure 16 present the achievable energy savings and emissions reduction potential across the adoption scenarios over the forecast period. By 2050, the Site Incentive scenario achieves 21% emissions savings from baseline, the Carbon Price scenario saves 24%, and the Carbon Price+ scenario saves 30%.

Figure 15. Achievable Potential, Energy Savings, All Adoption Scenarios

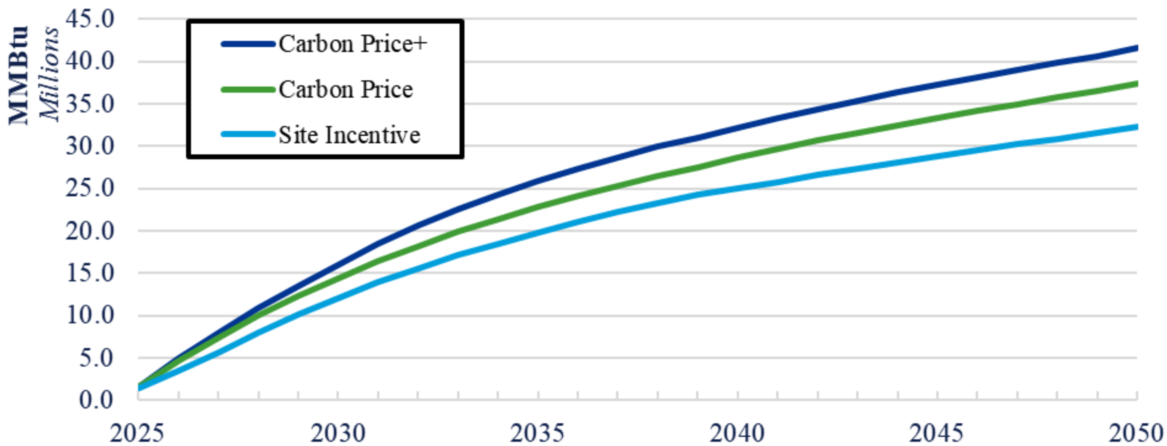
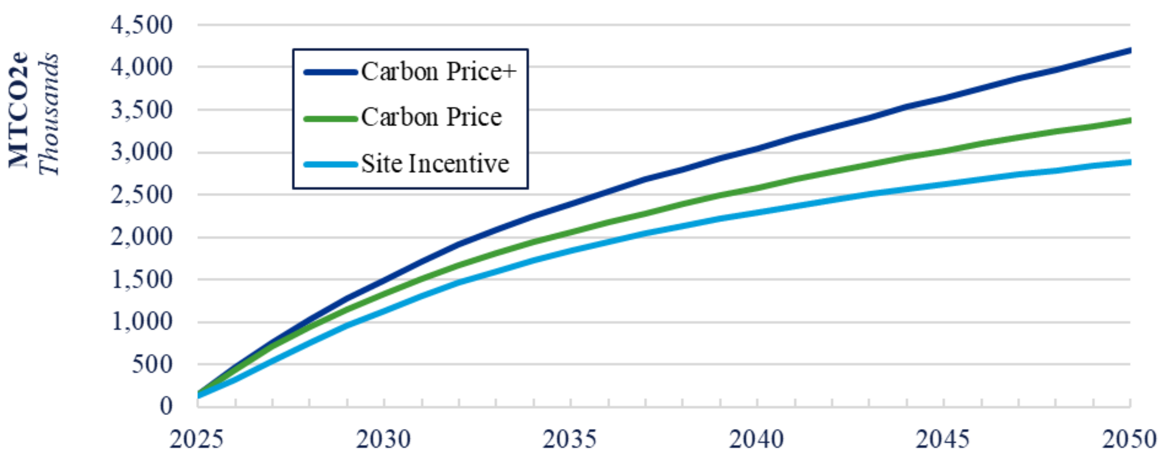


Figure 16. Achievable Potential, Emissions Reduction, All Adoption Scenarios



3.2.1 Achievable Potential by Category

Figure 17 breaks out energy savings by decarbonization category for each of the achievable potential scenarios in 2050. Electrification and energy efficiency dominate the attainable potential for all three scenarios. Electrification accounts for 55% of energy savings in the Carbon Price scenario, 57% in the Site Incentive scenario, and 60% in the Carbon Price+ scenario. Energy efficiency contributes a large share of energy savings as well, comprising 43% in the Site Incentive scenario, 45% in the Carbon Price scenario, and 41% in the Carbon Price+ scenario. Low-carbon fuels do not contribute to energy savings potential because they are energy neutral—savings in fossil fuels are offset by equivalent MMBtu of the low-carbon fuel. CCUS shows negative energy savings potential in the Carbon Price+ scenario because these measures reduce emissions but require energy to operate.

Figure 17. Achievable Potential by Scenario and Category, Energy Savings, 2050

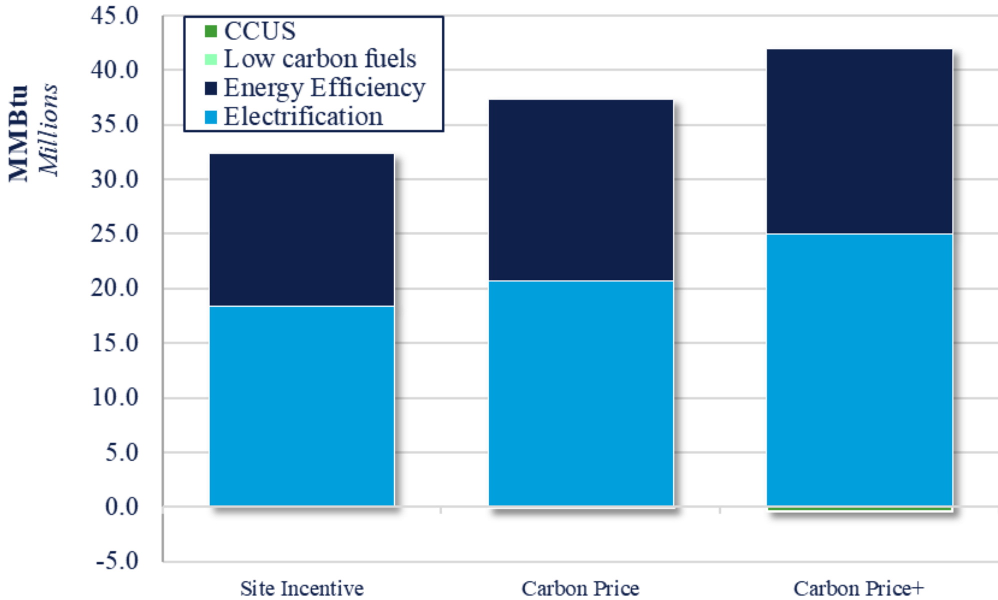
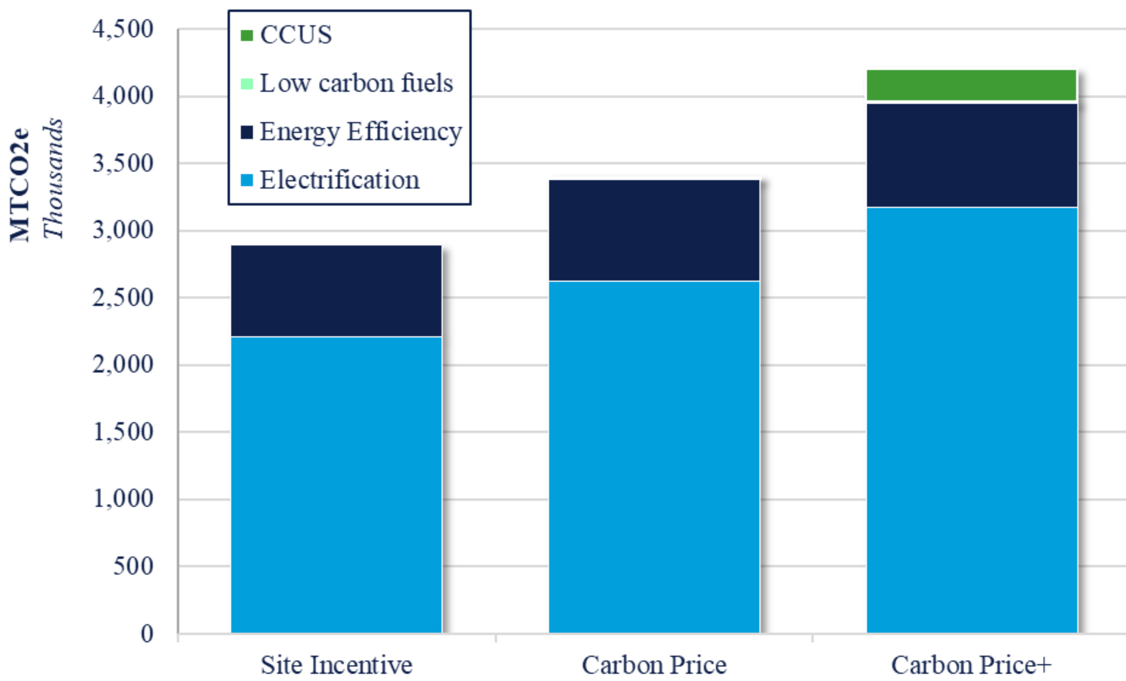


Figure 18 breaks out emissions savings by category for the achievable potential scenarios in 2050. Like energy savings, electrification and energy efficiency dominate the achievable potential for all three scenarios. Electrification accounts for 76% of savings in both the Site Incentive scenario and Carbon Price+ scenario, and 78% in the Carbon Price scenario. Energy efficiency contributes a lower share of emissions reductions than energy savings, with 24% in the Site Incentive scenario, 22% in the Carbon Price scenario, and 18% in the Carbon Price+ scenario. CCUS adoption is negligible in the Carbon Price scenario, but investments in barrier mitigation boost adoption to 6% in the Carbon Price+ scenario by 2050. Though such investments also increase adoption of low-carbon fuels, these fuels represent only a tiny share of potential in the Carbon Price+ scenario (0.03%, compared to 0.0004% in the Carbon Price scenario). Neither CCUS nor low-carbon fuels show any adoption in the Site Incentive scenario.

Figure 18. Achievable Potential by Scenario and Category, Emissions Reduction, 2050



Overall decarbonization potential in 2050 is 46% higher in the Carbon Price+ scenario than in the Site Incentive scenario. In both scenarios, achievable electrification potential exceeds economic potential. Many potential studies limit achievable potential to measures that pass the economic cost-effectiveness screen, making achievable measures a subset of economic ones so that achievable potential cannot exceed economic potential. By contrast, this study's achievable scenarios did not restrict incentives to measures that passed the societal benefit-cost screen. The modelled incentives cover up to 70% of the incremental cost to install a measure.

For electrification, the model results indicate an achievable potential that substantially exceeds what is economic under the defined cost-effectiveness parameters. For energy efficiency, however, achievable potential remains below economic potential in both the Site Incentive scenario (below 40% of economic across the study time frame) and the Carbon Price+ scenario (below 30% of economic). That is, even with the incentives allowed, substantial economic energy efficiency potential remains unadopted. In some cases, competition among measures results in the adoption of electrification measures ahead of energy efficiency; this competition partly explains why one category exceeds economic potential while the other falls short.

3.2.2 Energy Savings Achievable Potential by Fuel Type

Natural gas and net electricity use represent about 71% of total nonfeedstock energy consumption in the industrial sector, a key factor driving the relative energy savings potential by fuel.

Figure 19 and Figure 20[7] present the achievable energy savings for the Carbon Price+ scenario, broken out by fuel type for fuel-switching (Figure 19) and energy efficiency (Figure 20). The breakdown in Figure 19 highlights the increase in electricity and hydrogen consumption associated with energy savings from fuel-switching. Almost all fossil fuel savings from fuel-switching come from natural gas. Switching to electricity accounts for almost all the increased fuel use, with hydrogen fuel-switching only beginning to be adopted in 2044. By 2050, hydrogen will still account for only 0.2% of the increased fuel use. This trend is consistent across all scenarios, though hydrogen use appears only in the Carbon Price and Carbon Price+ scenarios.

Figure 19. Fuel-switching (Electrification + Low-carbon Fuels) Energy Savings Potential, Carbon Price+ Scenario

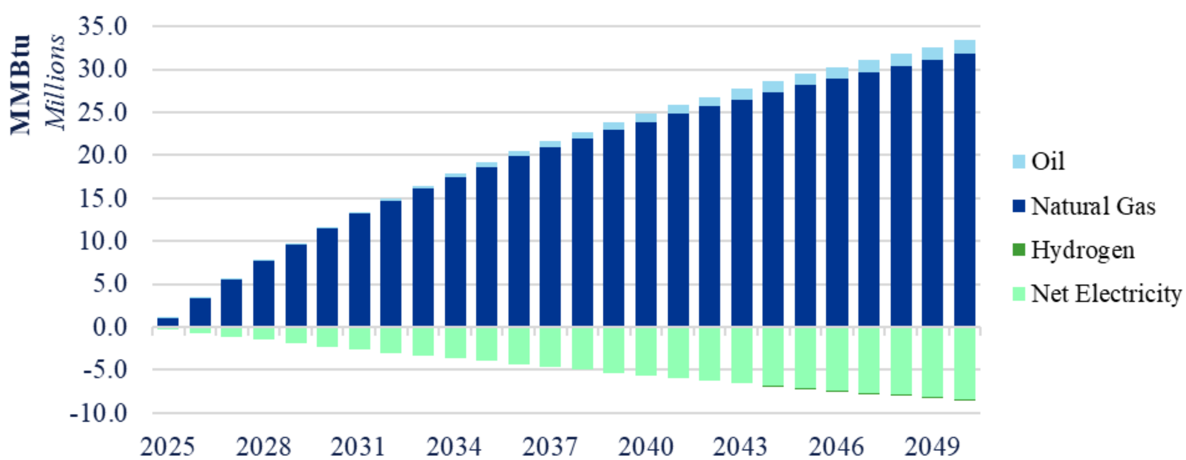


Figure 20 shows the energy efficiency and energy savings achievable under the Carbon Price+ scenario. Electricity and natural gas savings dominate, accounting for 51% and 44% of total savings, respectively. Coal and oil each account for less than 1%, while other fuels (primarily biomass in the Paper sector) account for 4%. Hydrogen savings, resulting from energy efficiency measures applied after a hydrogen fuel switch, are negligible.

Figure 20. Energy Efficiency Energy Savings Potential, Carbon Price+ Scenario

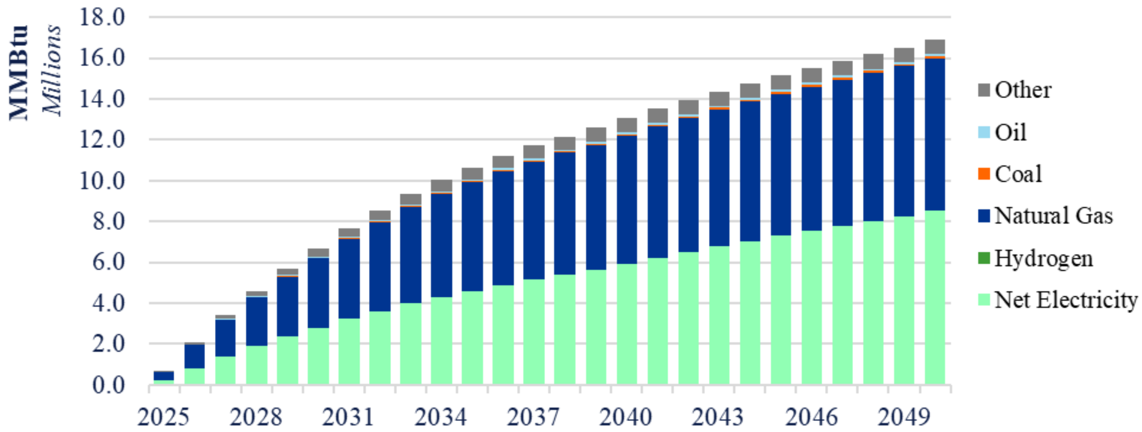
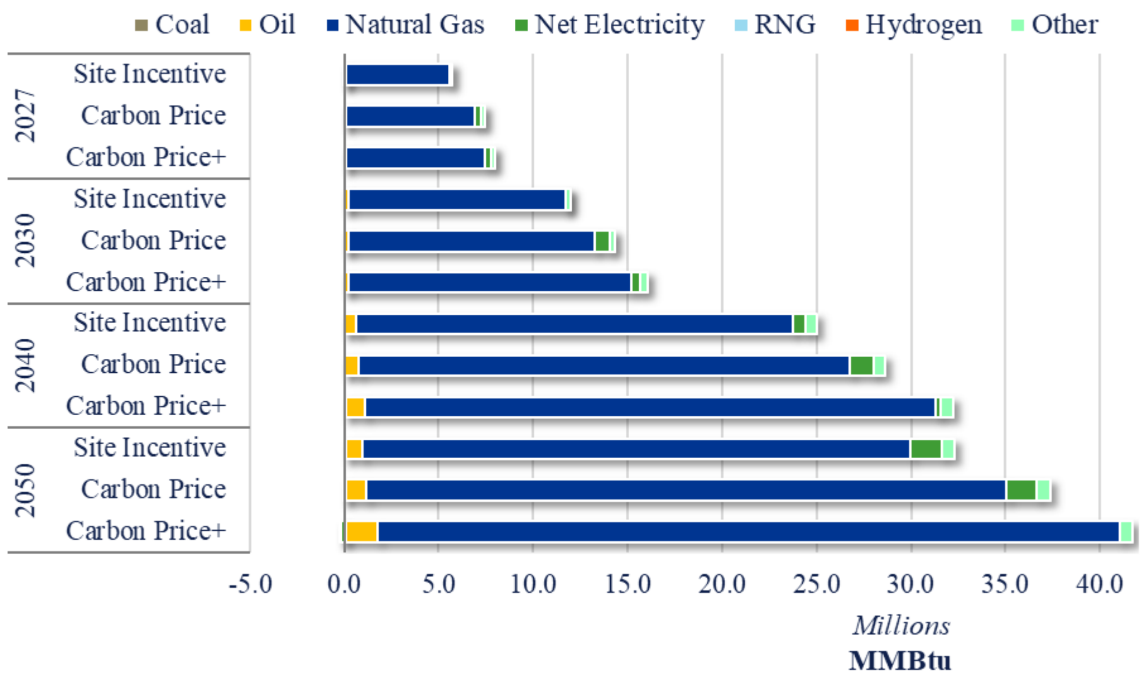


Figure 21 shows statewide achievable energy savings potential by scenario and fuel type for 2027, 2030, 2040, and 2050. By 2050, the Carbon Price+ scenario achieves energy savings equal to approximately 21% of total estimated baseline energy consumption (all fuels) and 30% of baseline fossil fuel consumption (natural gas, oil, and coal). By 2050, the Site Incentive scenario achieves savings equal to approximately 16% of total estimated baseline energy consumption and 23% of fossil fuel baseline consumption. In all scenarios, increases in electricity use from electrification and CCUS are offset by energy efficiency savings.

Figure 21. Achievable Potential Energy Savings by Scenario and Fuel, Selected Years



3.2.3 Achievable Potential by End Use

For energy savings, the share of achievable potential by end use is similar across scenarios, primarily because CCUS does not contribute to energy savings, and its associated energy penalty is relatively small compared to its carbon savings. Figure 22 and Figure 23 show the breakout of energy savings by end use for the Site Incentive and Carbon Price+ scenarios, respectively. In the Site Incentive scenario, process heating accounts for the largest share of energy savings at 64%, followed by boilers at 16% and facility HVAC at 10%. In the Carbon Price+ scenario, the corresponding shares are 63% for process heating, 18% for boilers, and 12% for facility HVAC. Motors account for 3.6% of energy savings in the Site Incentive scenario and 3% in the Carbon Price+ scenario. Although emissions savings from the decline over time due to grid decarbonization, more efficient electric motors continue to contribute to energy savings over the forecast period. This end use, which includes compressed air, fans, pumps, and drives, is a cost-effective source of energy savings and will continue to play a role in industrial energy efficiency programs, as well as offering grid benefits.

Figure 22. Energy Savings Potential by End Use, Site Incentive Scenario

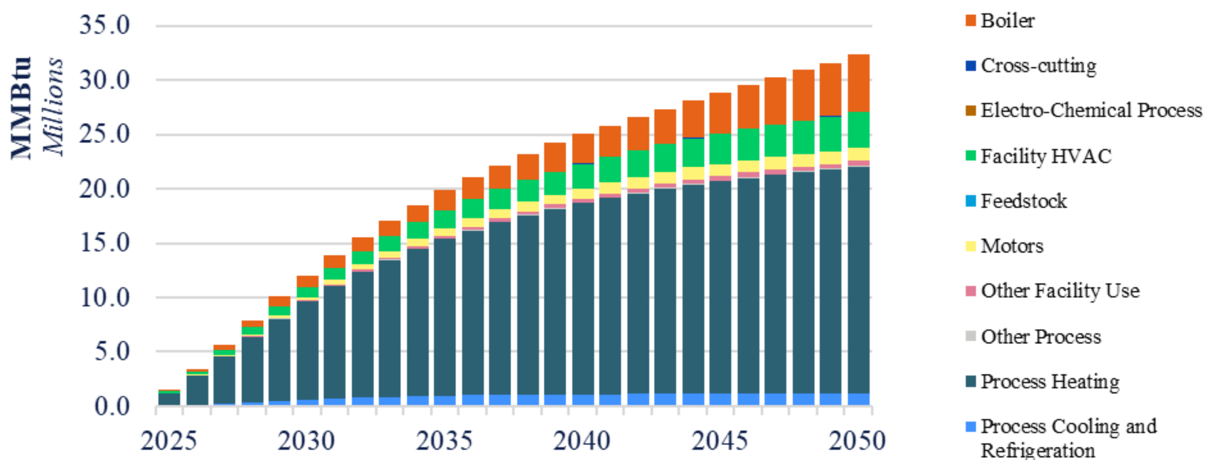
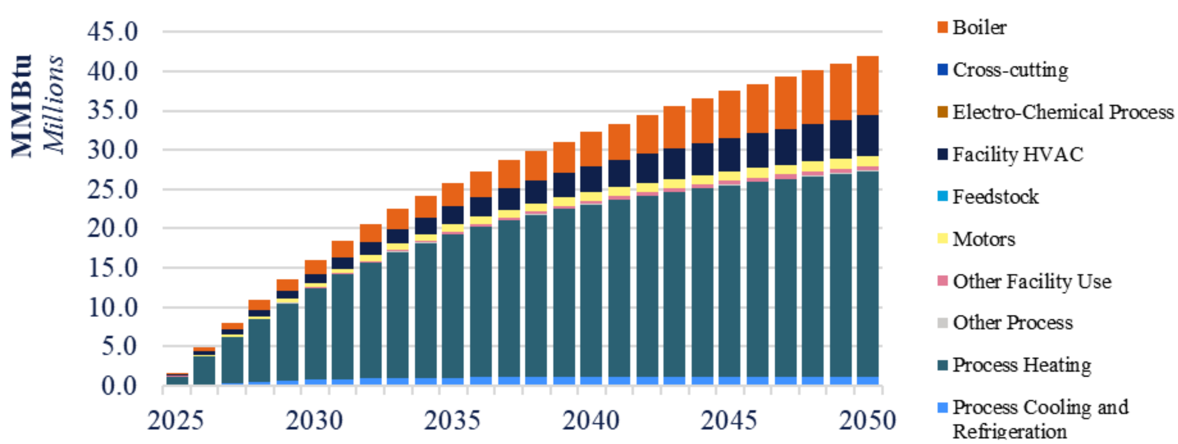


Figure 23. Energy Savings Potential by End Use, Carbon Price+ Scenario



For emissions, process heating measures again account for the majority of achievable savings: 79% for the Site Incentive scenario and 72% for the Carbon Price+ scenario. Process heating includes a wide range of measures—some, such as process controls, are broadly applicable across industries and equipment types; others are industry-specific or have more limited applicability, such as electric resistance melting in the glass industry or efficient ladle preheating in Primary Metals. In both energy and emissions, process heating savings increase between the Site Incentive and Carbon Price+ scenarios (Figure 22 and Figure 23, respectively, for energy; Figure 24 and Figure 25 for emissions), but its share of total emissions savings declines in the Carbon Price+ scenario.

The second- and third-largest sources of emissions savings in both scenarios are facility HVAC (13%–14%) and boilers (7%). Motors contribute only a small share of emissions savings, and that share declines over time as the grid decarbonizes. The most notable difference between scenarios in terms of emissions reduction, besides process heating, is in the cross-cutting end use. In the Site Incentive scenario, emissions reductions from cross-cutting measures are negligible, while the Carbon Price+ scenario sees about 6% of its potential in this category, driven almost entirely by CCUS. Other cross-cutting measures include strategic energy management and high-efficiency transformers, although their contribution to emissions reduction is comparatively small.

Figure 24. Emissions Reduction Potential by End Use, Site Incentive Scenario

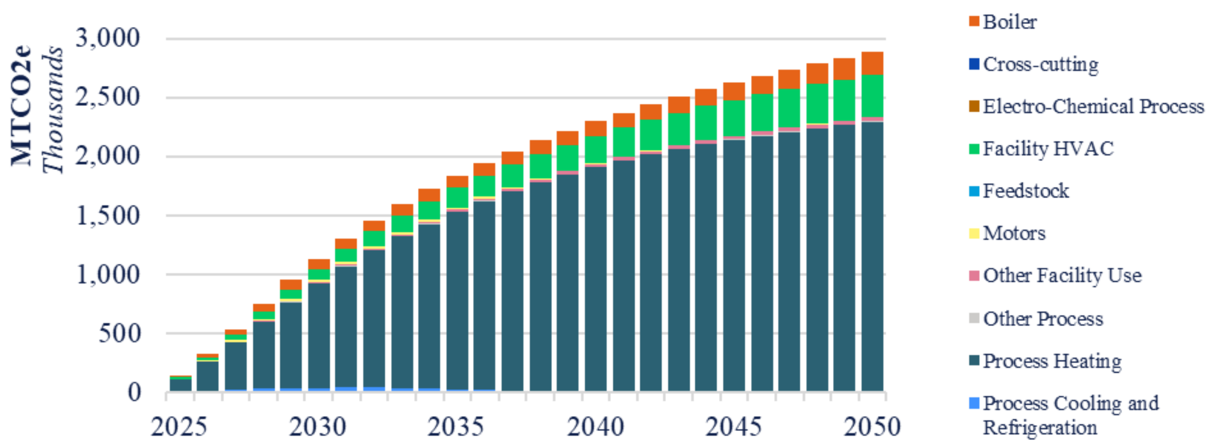


Figure 25. Emissions Reduction Potential by End Use, Carbon Price+ Scenario

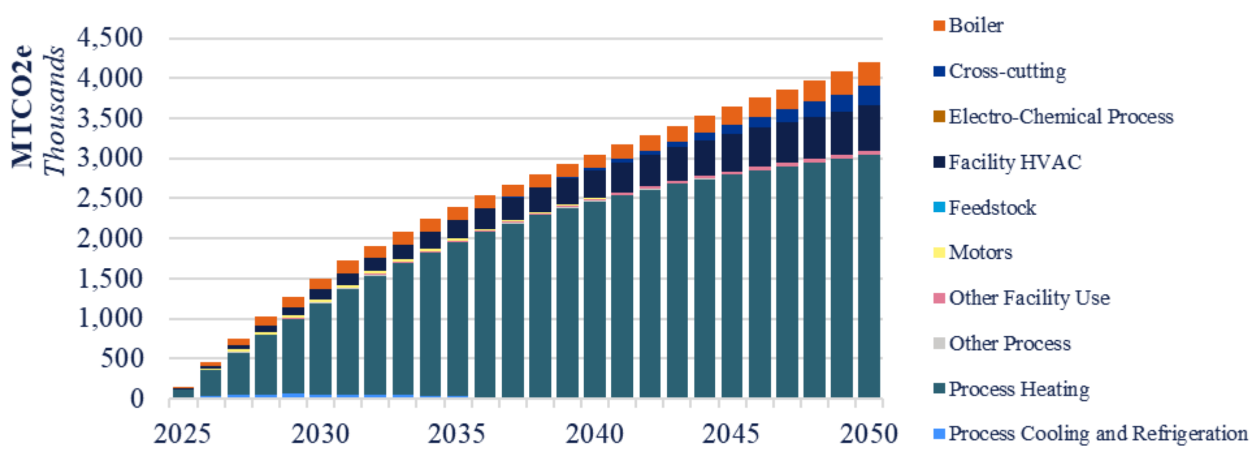


Figure 26, Figure 27, and Figure 28 show energy and emissions savings for process heating and non-process heating end uses for the Carbon Price+ scenario, and emissions savings for the Site Incentive scenario. Process heating is further broken out by temperature. Early in the forecast, low-temperature heat accounts for about half of the year-over-year growth in both energy savings and emissions. By 2050, however, growth in low-temperature heat slows, while growth in medium-temperature heat accelerates, accounting for 58% of the year-over-year growth in energy savings and 36% of year-over-year growth in emissions reduction potential in the Carbon Price+ scenario.

For comparison, Figure 29 shows the contribution of baseline process heat emissions from each temperature category in 2023, with medium heat comprising the largest share. While the overall emissions reduction potential is lower in the Site Incentive scenario compared to the Carbon Price+ scenario, the relative contributions of each temperature category are similar in both scenarios.

Figure 26. Achievable Potential by Process Heat Temperature Range, Carbon Price+ Scenario, Energy Savings, 2025–2050

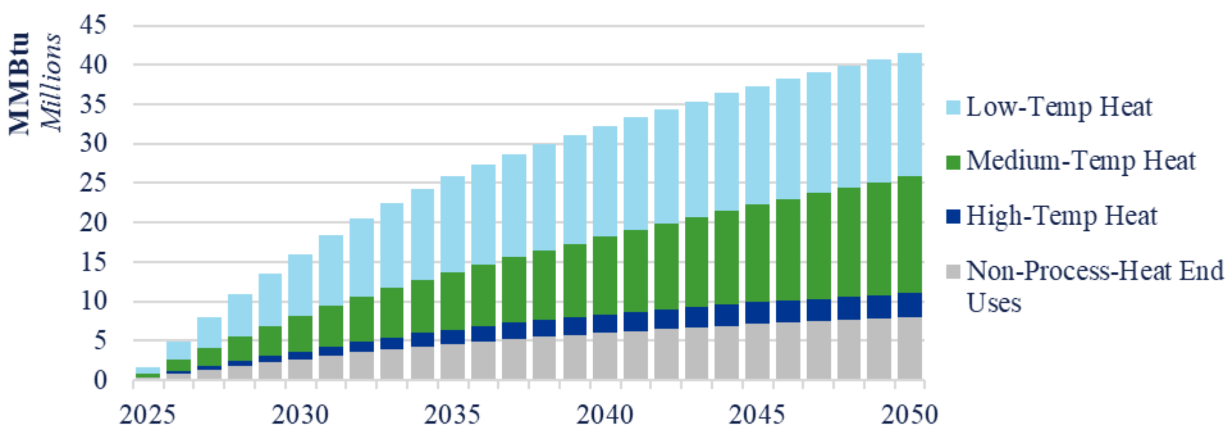


Figure 27. Achievable Potential by Process Heat Temperature Range, Carbon Price+ Scenario, Emissions Reduction, 2025–2050

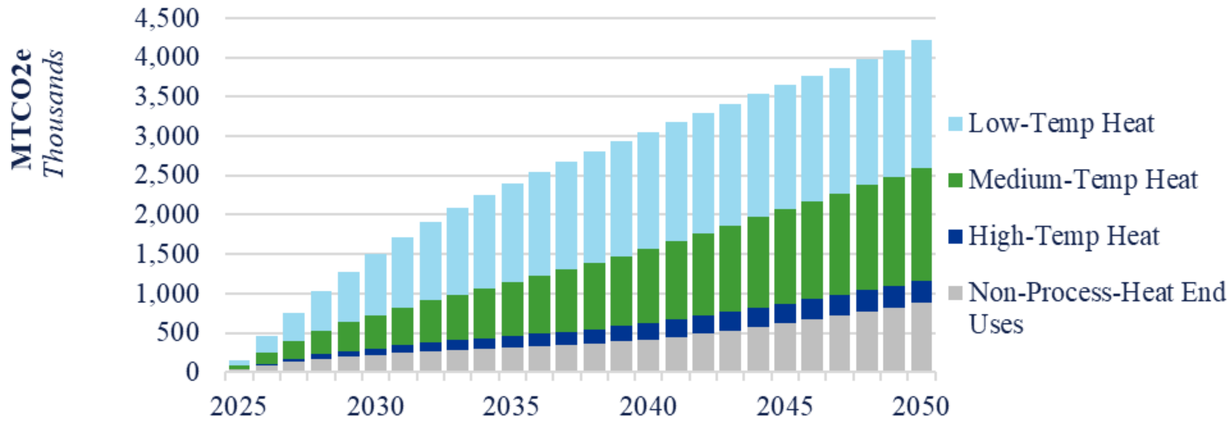


Figure 28. Achievable Potential by Process Heat Temperature Range, Site Incentive Scenario, Emissions Reduction, 2025–2050

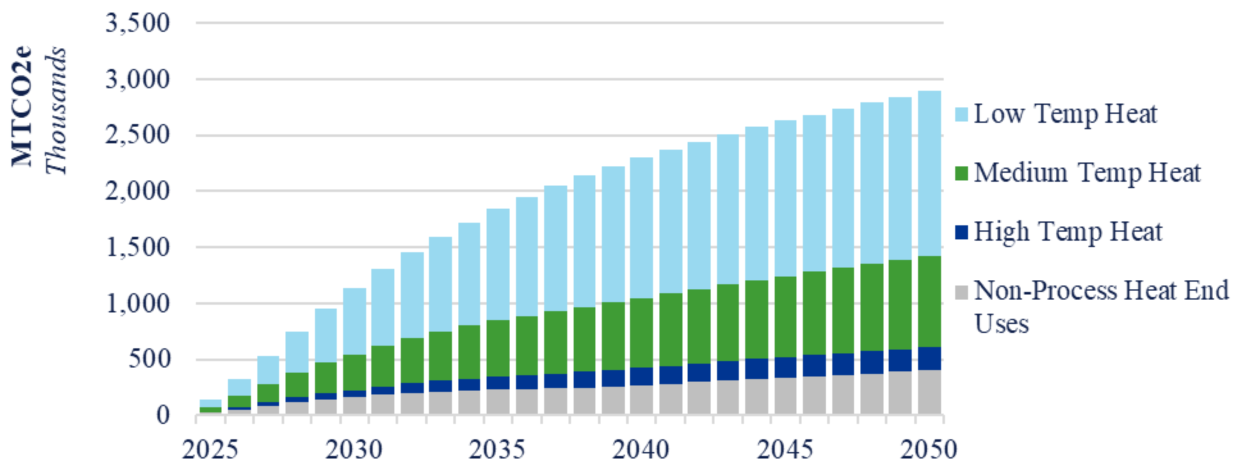
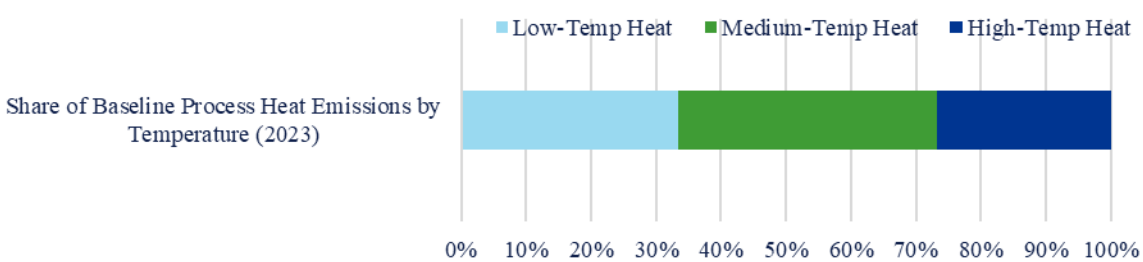


Figure 29. Share of 2023 Baseline Process Heat Emissions by Temperature Range



3.2.4 Achievable Potential by Subsector

The four largest energy-consuming subsectors in New York State's Industrial Manufacturing sector are Paper, Chemicals, Primary Metals, and Food. Among these, the Paper subsector has the largest share of "other" fuels in its baseline consumption, primarily from biomass sources such as wood, bark, and paper waste. This reliance on biomass limits the benefits of fuel-switching in this sector.

For energy savings by subsector, Chemicals and Food consistently rank first and second in most scenarios by 2025. In the Carbon Price scenario, they account for 19% and 18%, respectively, and in the Carbon Price+ scenario, 21% and 17%, respectively, in 2050. However, in the Site Incentive scenario, the rankings are reversed: Food leads with 19%, while Chemicals follow at 17%. The combined "Other" subsector ranks third across all scenarios, contributing between 15% to 16% of the share, and Transportation Equipment ranks fourth, with a share of 12% to 14%.

Figures 30 and 31 show the energy savings for the Site Incentive and Carbon Price+ scenarios by subsector.

Figure 30. Energy Savings Potential by Subsector, Site Incentive Scenario

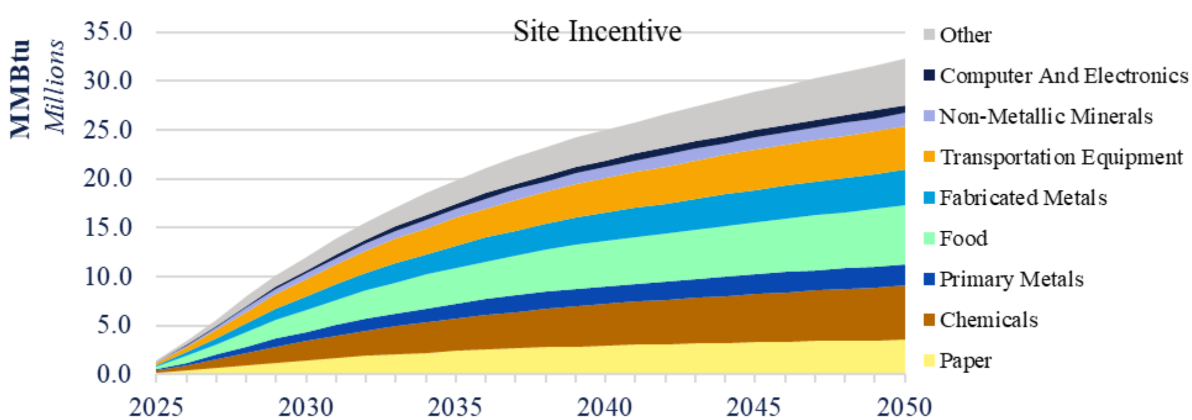
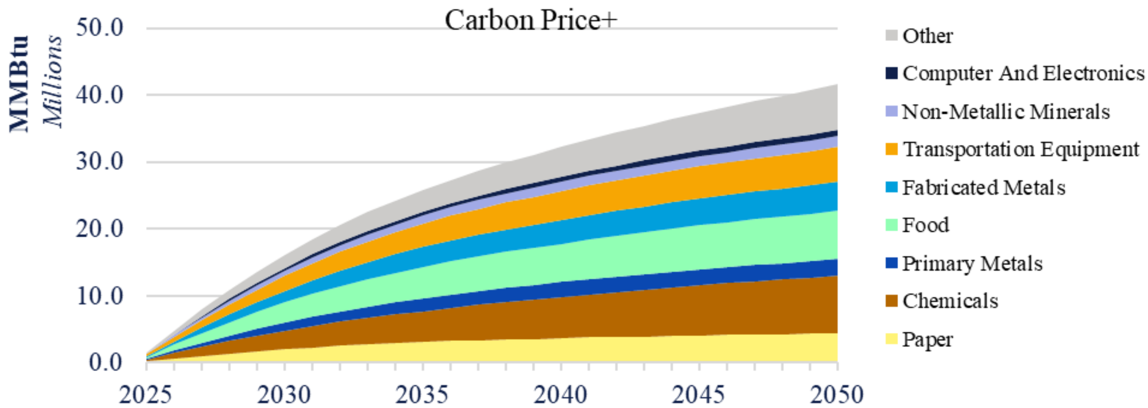


Figure 31. Energy Savings Potential by Subsector, Carbon Price+ Scenario



Emissions reduction by subsector shows greater variation compared to energy savings. In the Carbon Price and Carbon Price+ scenarios, the Chemicals subsector holds the largest share of emissions reduction potential, representing 17% and 25% of total, respectively. This is largely driven by opportunities in process heating and CCUS opportunities (in the Carbon Price+ scenario) available in this subsector.

Transportation Equipment and Food rank second and third in both scenarios, each accounting for about 17% of emissions reductions in the Carbon Price scenario and 15% in the Carbon Price+ scenario.

In contrast, the Site Incentive scenario presents a different ranking: Transportation Equipment and Food lead with 18% each, followed by Chemicals at 13%. This shift occurs because emission reductions from process heating electrification, which make up a sizable share of the Chemicals subsector's savings under the other scenarios, are less impactful in the Site Incentive scenario.

Figures 32 and 33 show emissions reduction potential by subsector for the Site Incentive and Carbon Price+ scenarios.

Figure 32. Emissions Reduction Potential by Subsector, Site Incentive Scenario

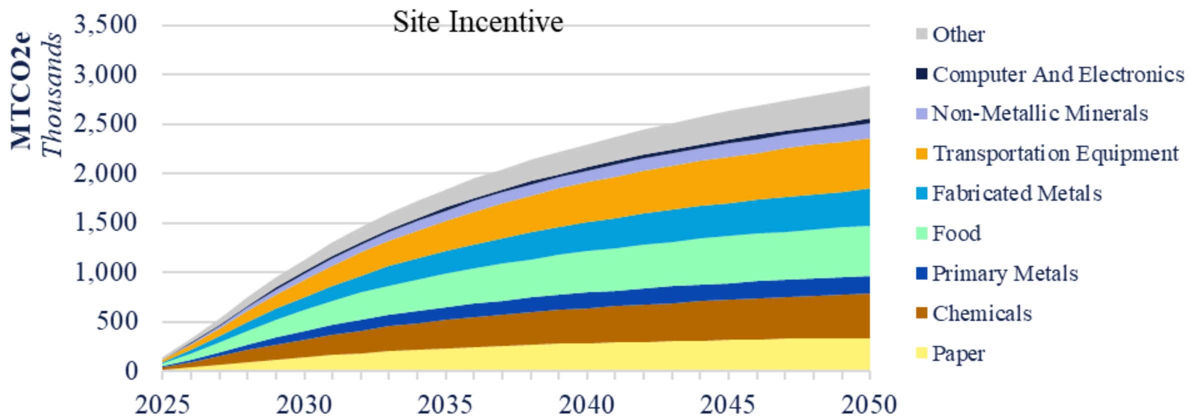
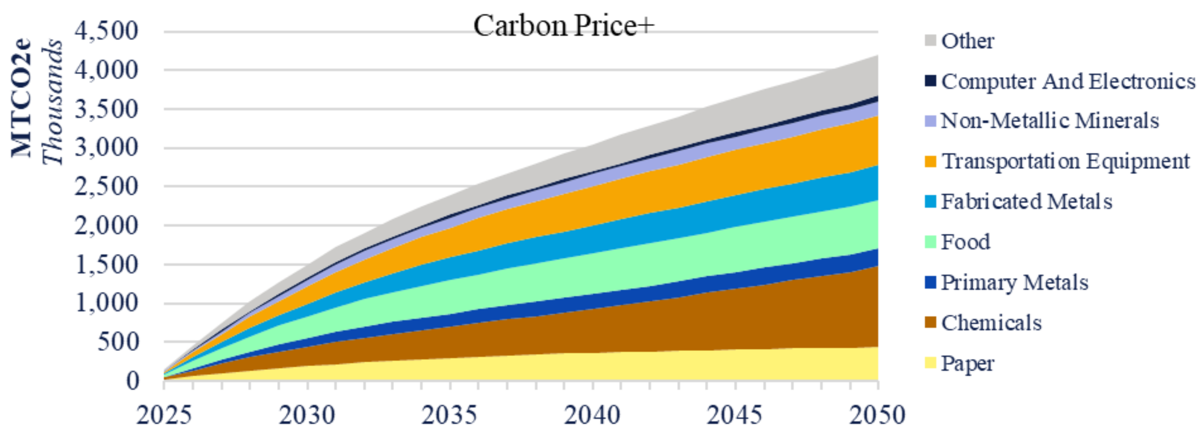


Figure 33. Emissions Reduction Potential by Subsector, Carbon Price+ Scenario



3.2.5 Achievable Potential by NYISO Zone

This section presents energy savings and emissions reduction potential broken out by the NYISO's 11 load zones (Figure 34). NYISO identifies these zones by both name and letter. From west to east and north to south, the zones are: (A) West, (B) Genesee, (C) Central, (D) North, (E) Mohawk Valley, (F) Capital, (G) Hudson Valley, (H) Millwood, (I) Dunwoodie, (J) New York City, and (K) Long Island. The focus here is on achievable potentials for 2050, specifically within the Site Incentive and Carbon Price+ scenarios. Appendix B provides additional results by zone and DACs.

Understanding regional differences requires knowledge of how the Industrial subsectors' composition varies across the State. Figure 35 shows each zone's baseline energy use broken out by subsector. Because no two sectors have the same industrial makeup, variations in energy savings and emissions reduction potential by subsector largely explain the differences in potential across zones.

Figure 34. NYISO Zone Map

Source: NYISO (2023).

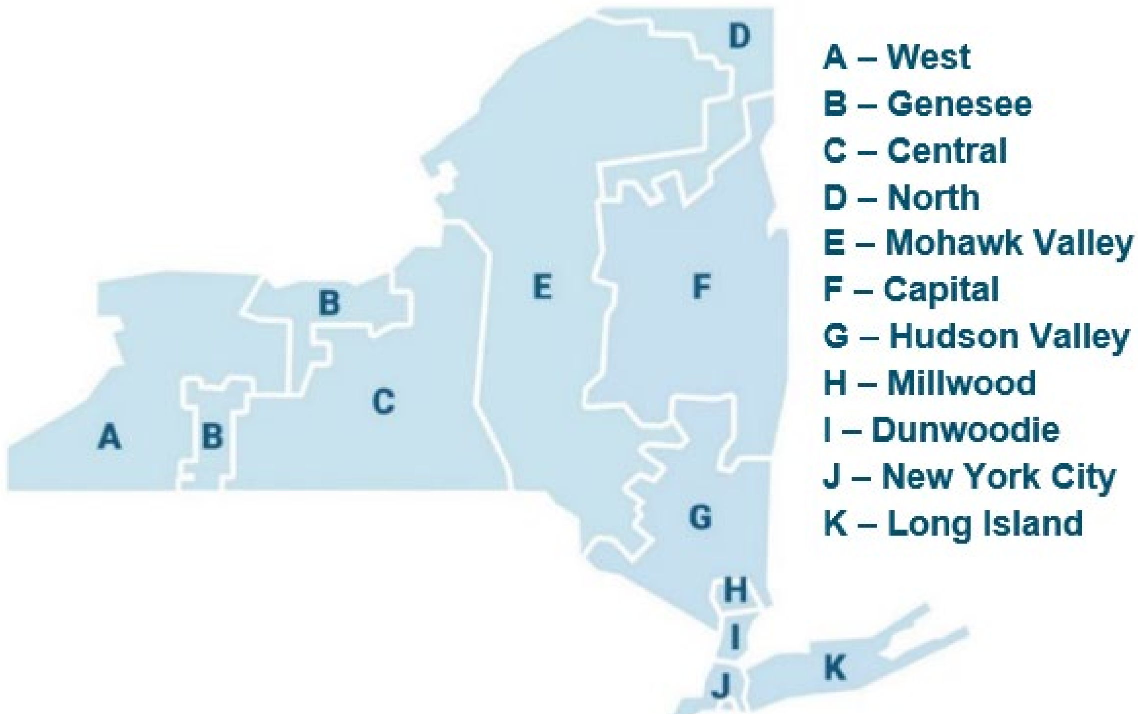
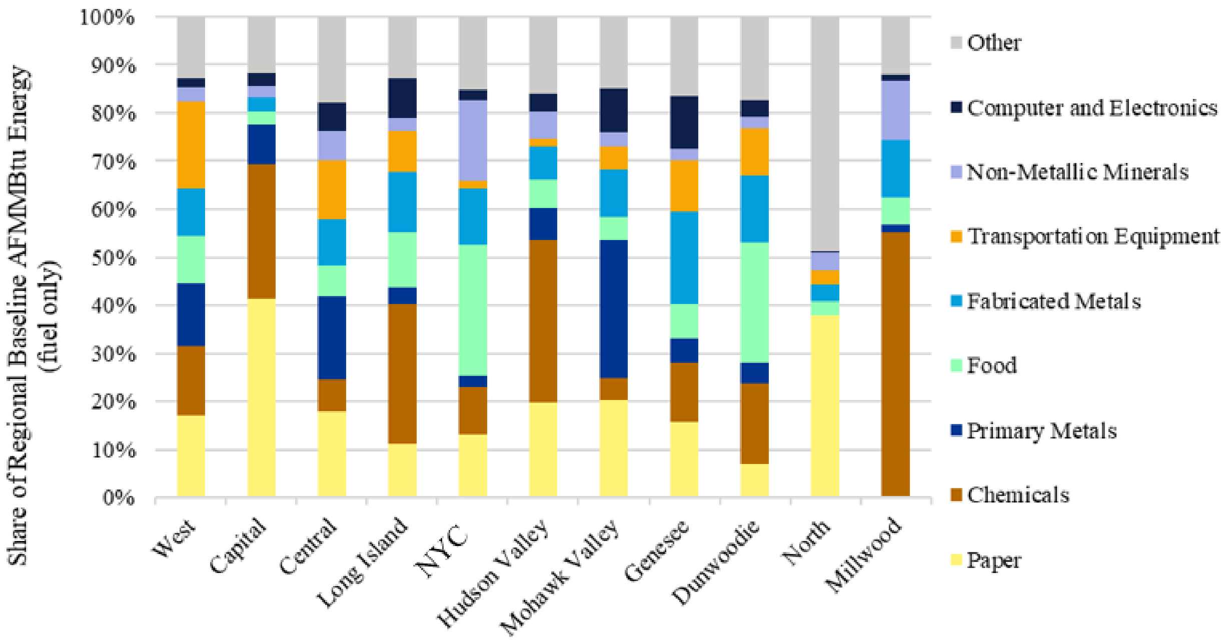


Figure 35. Share of 2023 Baseline Energy Consumption by Subsector in Each NYISO Zone

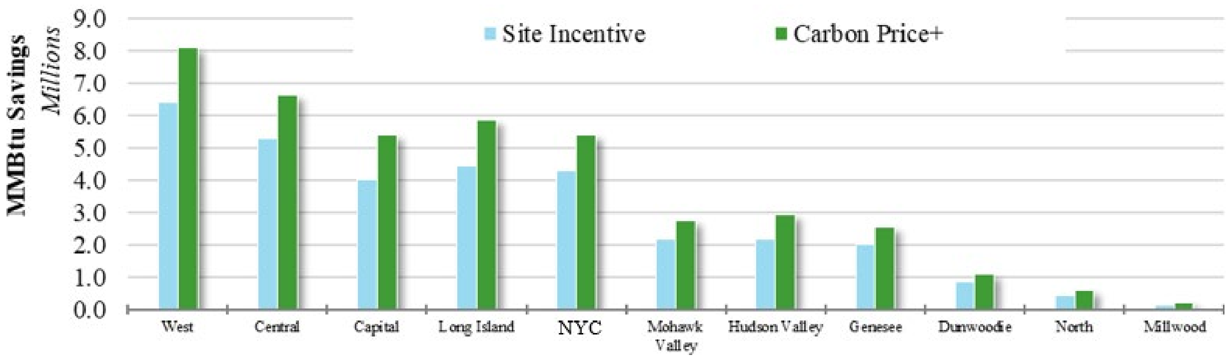


Metric	NYISO Zone										
	West	Capital	Central	Long Island	NYC	Hudson Valley	Mohawk Valley	Genesee	Dun-woodie	North	Mill-wood
2023 total energy consumption (million MMBtu)	29.9	27	27.6	21.9	18.4	12.8	12.9	10	3.6	2.8	0.8

Figure 36 presents energy savings potential by NYISO zone for the Site Incentive and Carbon Price+ scenarios, with the zones on the x-axis ordered according to their 2050 baseline energy use. The West zone has the highest energy savings potential, accounting for 20% of the State's total energy savings potential in the Site Incentive scenario and 25% in the Carbon Price+ scenario. Next is Central, contributing between 16% and 21% of the State's total energy savings potential, followed by Long Island with between 14% and 18%, and New York City with between 13% and 17%. Though the Capital zone has the third-highest baseline energy use, it has the lowest savings potential relative to its baseline, with only 15% to 20% savings of its energy use.

Figure 36. 2050 Achievable Energy Savings Potential by Zone Compared to Baseline Consumption, Site Incentive and Carbon Price+ Scenarios

Achievable energy savings potential in 2050 by NYISO zone, compared to baseline consumption for the Site Incentive scenario and the Carbon Price+ scenario.



Metric	NYISO Zone										
	West	Central	Capital	Long Island	NYC	Mohawk Valley	Hudson Valley	Genesee	Dun-woodie	North	Mill-wood
2050 baseline (million MMBtu)	29.9	27.6	27.0	21.9	18.4	12.9	12.8	10.0	3.6	2.8	0.8
Site Incentive as a % of 2050 baseline	21%	19%	15%	20%	23%	17%	17%	20%	24%	16%	19%
Carbon Price+ as a % of 2050 baseline	27%	24%	20%	27%	29%	21%	23%	26%	31%	21%	28%

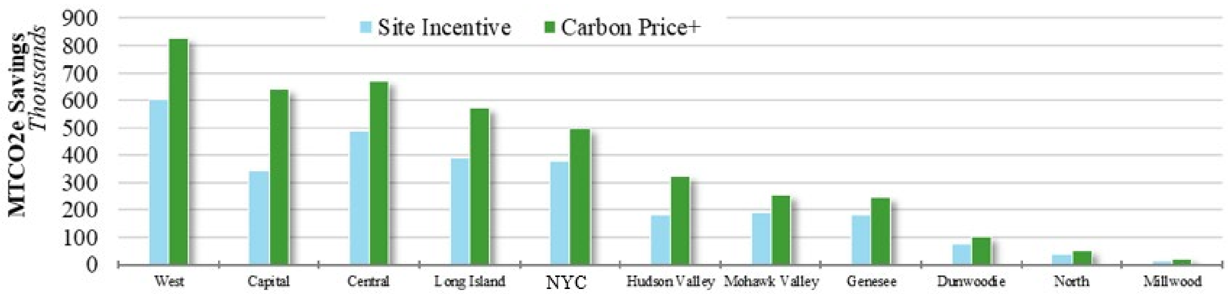
Figure 37 presents the carbon savings potential by NYISO zone for 2050 for the Site Incentive and Carbon Price+ scenarios, with zones on the x-axis sorted by 2050 descending baseline emissions. The West zone has the highest total emission reduction potential in both scenarios, 20% of total potential, or between 600 thousand and 800 thousand $MtCO_2$ in 2050. Central follows at 16%–17%, Capital at 12%–15%, and Long Island at 14% of total emissions savings.

In both scenarios, West and Dunwoodie have the highest percent decarbonization potential, reducing approximately one-quarter to one-third of their regional emissions. The Capital and Hudson Valley zones show the largest increases in decarbonization potential between scenarios, with potential increasing 87% and 75%, respectively, driven by a substantial savings boost from CCUS, which makes up 21% of Capital's savings and 15% of Hudson Valley's savings in the Carbon Price+ scenario.

Comparing each zone's share of energy savings to its share of baseline consumption shows that West, Long Island, Genesee, and Dunwoodie have disproportionately high savings. New York City's share of energy savings exceeds its share of baseline use for both adoption scenarios. Although Central had disproportionately high emissions savings, it achieves less-than-proportional energy savings.

Figure 37. 2050 Achievable Decarbonization Potential by Zone Compared to Baseline Emissions, Site Incentive and Carbon Price+ Scenarios

Achievable emissions reduction potential in 2050 by NYISO zone, compared to baseline emissions, the Site Incentive scenario, and the Carbon Price+ scenario.



	West	Capital	Central	Long Island	NYC	Hudson Valley	Mohawk Valley	Genesee	Dun-woodie	North	Mill-wood
2050 Baseline (thousand $MTCO_2e$)	2,515	2,264	2,221	1,875	1,719	1,101	949	790	304	214	79
Site Incentive as a % of 2050 baseline	24%	15%	22%	21%	22%	17%	19%	23%	25%	17%	16%
Carbon Price+ as a % of 2050 baseline	33%	28%	30%	31%	29%	23%	34%	31%	34%	25%	25%

Variation across zones reflects differences in the mix of industries and their relative emissions savings potential. Subsectors with particularly low potential as a percentage of base are Paper, Primary Metals, Computer and Electronics, and, in the Site Incentive scenario only, the aggregated Other category. The Capital zone's largest subsectors are Paper (41% of base energy use) and Chemicals (28%), so its relatively low savings potential as a percentage of base is unsurprising, and it ranks better in the Carbon Price+ scenario than in the Site Incentive scenario. Subsectors with significantly above-average potential include Food, Fabricated Metals, and Transportation Equipment. In the Carbon Price+ scenario only, Chemicals also show high potential due to substantial CCUS savings in this subsector, which has a lot of emissions reduction potential in this scenario.

Of all the zones, Dunwoodie has the highest share of base energy use in Food, Fabricated Metals, and Transportation Equipment (66%). Its share of emissions reduction potential (2.6% for the Site Incentive scenario and 2.4% for the Carbon Price+ scenario) exceeds its share of base use (2.2%). Other zones with disproportionately high potential include West (20% to 21% of potential compared to 18% of base) and Central (15.9% to 16.9% of potential compared to 15.8% of base). New York City's share of emissions reduction potential in the Site Incentive scenario (13.1%) is higher than its share of base emissions (12.3%), but the opposite holds in the Carbon Price+ scenario (11.8% share of potential). Non-Metallic Minerals and Food each make up a larger share of base energy use in New York City than any other zone, with Food likely driving outperformance in the Site Incentive scenario and Non-Metallic Minerals (with its nonenergy emissions) likely contributing to underperformance under the Carbon Price+ scenario.

In most zones, the percentage of emissions reduction exceeds the percentage of energy savings. Exceptions are New York City and Millwood in both scenarios; Hudson Valley is an exception in the Site Incentive scenario only. These three zones have a larger-than-average presence of Chemical or Non-Metallic Minerals, both of which involve nonfuel energy use and emission reduction potential from CCUS.

3.2.6 Breakthrough Scenarios and Fuel Sensitivities

The study team also modelled two additional scenarios to explore the impacts of technology and fuel price changes:

- **Electrification Breakthrough**
  This scenario used the same assumptions as the Carbon Price+ scenario, but incorporated breakthrough electrification technologies for high-temperature process heating, including lime kilns and sinter kilns. These technologies assume more aggressive improvements in cost and performance for electric heating measures.
- **Hydrogen Breakthrough**
  This scenario also built on the Carbon Price+ scenario assumptions, but it used an optimistic hydrogen price forecast, based on the recently published "New York State Hydrogen Assessment, Final Report," instead of the conservative estimates used in the Carbon Price+ scenario (NYSERDA 2025).

The results of the breakthrough scenarios did not differ substantially from the Carbon Price+ scenario. The Hydrogen Breakthrough scenario showed energy savings and emissions reduction potential almost identical to the Carbon Price+ scenario throughout the study period. The Electrification Breakthrough scenario yielded slightly higher results, roughly 2%–3% higher than the Carbon Price+ scenario in the outer years. Because of this, the study team does not discuss the results of these scenarios in further detail.

In addition to the breakthrough scenarios, the study team conducted fuel price sensitivity analyses to assess how changes in fuel prices would impact the potential. The team explored the following (all price changes are in real dollars):

- **Electricity Price Scenarios**
  - Price trajectory adjusted so that price doubles by 2050
  - Price trajectory adjusted to achieve a 50% reduction by 2050
- **Natural Gas Price Scenarios**
  - Price trajectory adjusted so that price doubles by 2050
  - Price trajectory adjusted to achieve a 50% reduction by 2050
- **Combined Price Scenarios**
  - High electricity/low gas price scenario: electricity price doubles by 2050, paired with the natural gas price declining 50% by 2050
  - Low electricity/high gas price scenario: electricity price declines 50% by 2050, paired with the natural gas price doubling by 2050

Price changes affect potential in several ways. Other factors being equal, lowering electricity prices would make electrification more beneficial to the customer and increase adoption of that measure category. Still, electric energy efficiency measures would become less cost-effective, decreasing adoption of that measure category. Higher natural gas prices would similarly encourage electrification, and would encourage natural gas energy efficiency and improve cost-effectiveness for low-carbon fuels.

Sensitivity runs investigated the effect of different prices on potential under the Site Incentive scenario. These runs found that low electricity price assumptions increased potential in 2050 by 1.3% compared to the Site Incentive scenario results presented in this report. High natural gas prices assumptions increased potential by 14.1%, and the combined low electricity/high natural gas prices increased potential by 16.3%.

In the opposite direction, high electricity price assumptions decreased potential in 2050 by 2.9%, low natural gas prices reduced potential by 9.7%, and the combination of high electricity/low natural gas prices decreased potential by 12%, all compared to the Site Incentive potential scenario results.[8]

3.3 Peak Demand Potential Results

In addition to GHG emissions and energy savings, the study estimated peak demand impacts for electricity and natural gas. Industrial demand is relatively flat with respect to time of day and season compared to other sectors, since process energy use is not weather sensitive, and many large facilities operate two or three shifts. Where HVAC is a major driver of peak in the residential and commercial sectors, it represents only 10% of industrial baseline use and is more influenced by internal loads than outdoor temperature.

Table 5 shows the 2050 statewide demand impact potential by fuel from energy efficiency, electrification, low-carbon fuels, and CCUS measures modelled in this analysis. Electricity results reflect net impacts, accounting for both electricity savings from energy efficiency and increased electricity use from electrification, CCUS, and thermal storage. Net electricity peak demand savings range from 3.4% of baseline in the Carbon Price+ scenario to 4.8% in the Carbon Price scenario. Natural gas peak demand reductions are much higher proportionately, at 35%–36%, due to the combined impacts of electrification and energy efficiency.

All modelled scenarios result in a net reduction in electricity demand. These results are independent of demand impacts from demand response programs or interruptible rate impacts, which are included in the baseline.

Table 5. 2050 Statewide Electricity and Gas Demand Impact Potential

Fuel type	Units	Estimated 2050 base manufacturing peak	Demand impact achievable potential: Site Incentive	Demand impact achievable potential: Carbon Price	Demand impact achievable potential: Carbon Price+
Net Electricity	Summer Peak MW	2,358	99	114	80
Natural Gas	Winter Peak MMBtu-Day	244,993	84,201	87,410	88,340

Figure 38 and Figure 39 break out demand savings by measure category for natural gas in the Site Incentive and Carbon Price+ scenarios, respectively. In Figure 38, natural gas peak savings are shown by category, with electrification accounting for about three-quarters of the peak day reduction, and energy efficiency making up most of the balance.

Figure 38. Achievable Natural Gas Demand Impact Potential by Category, Site Incentive Scenario

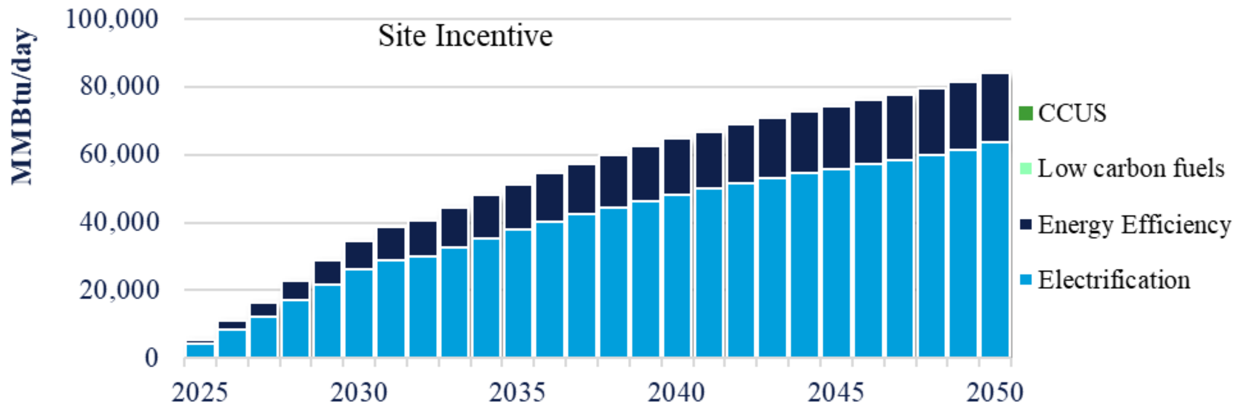


Figure 39. Achievable Natural Gas Demand Impact Potential by Category, Carbon Price+ Scenario

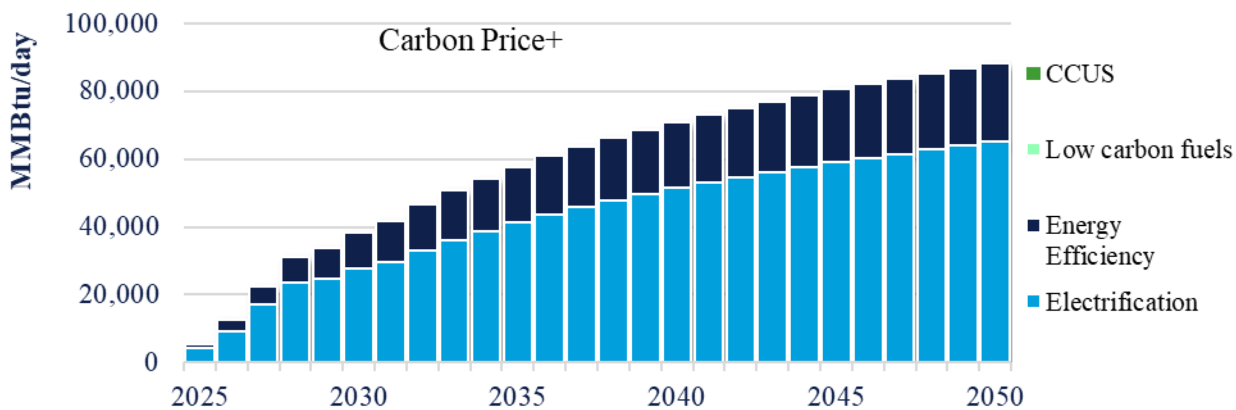


Figure 40 and Figure 41 show the corresponding electricity demand impacts for each adoption scenario. The picture is more complex, with energy efficiency producing peak savings, while electrification and CCUS add to peak demand. appearing as negative savings in the chart. Energy efficiency impacts dominate, resulting in a small overall net savings. In the Carbon Price+ scenario, energy efficiency demand savings are about one-third higher than the combined electrification and CCUS additions; for the Site Incentive scenario, the savings are 69% higher.

Figure 40. Achievable Electric Demand Impact Potential by Category, Site Incentive Scenario

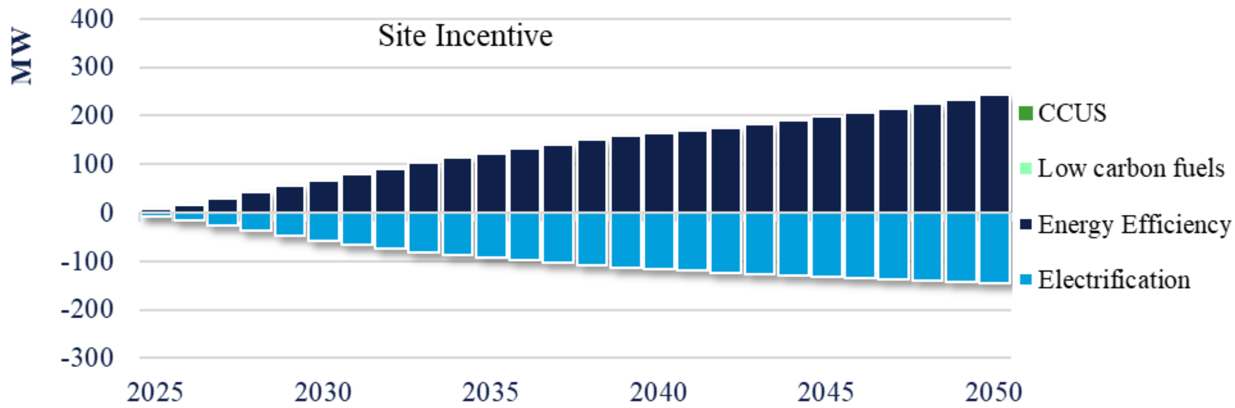
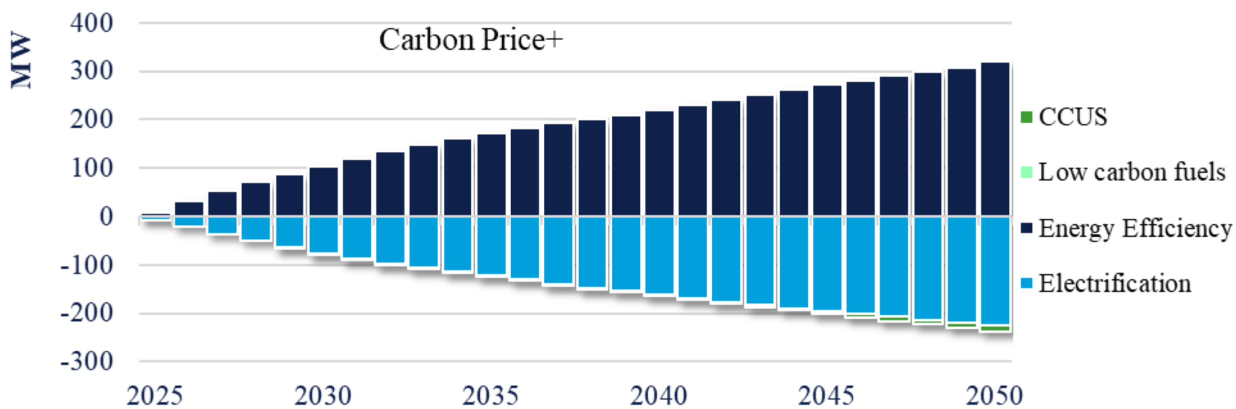


Figure 41. Achievable Electric Demand Impact Potential by Category, Carbon Price+ Scenario

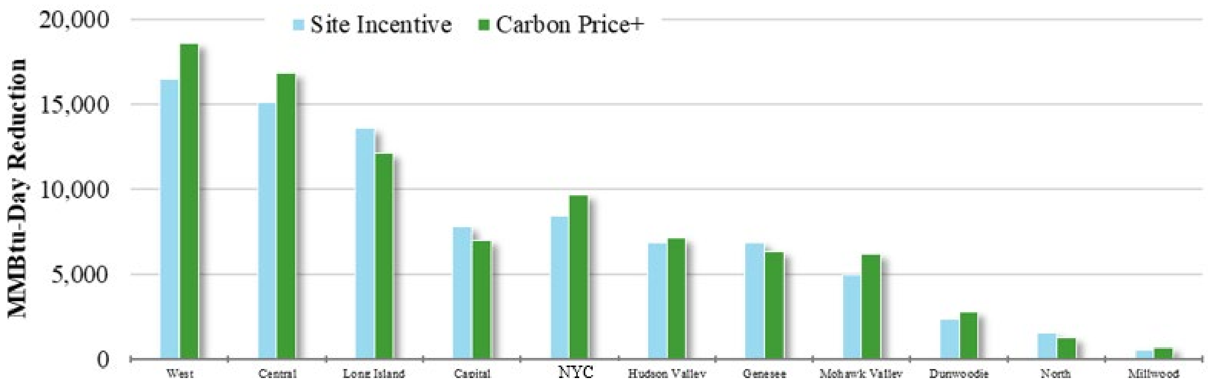


3.3.1 Peak Demand Potential by Zone

The following figures present the peak impacts by zone and fuel in 2050 for the Site Incentive and Carbon Price+ scenarios. The x-axis is sorted by 2050 regional baseline peak demand, for each respective fuel, from largest to smallest. Natural gas peak day savings by zone (Figure 42) largely follows the same pattern as the baseline gas peak. West and Central have the highest savings in absolute terms, comprising roughly 40% of potential peak demand savings between the two regions in each scenario. The Capital zone saves the least compared to baseline demand, with savings potential of 23% of baseline demand in the Site Incentive scenario and 21% in the Carbon Price+ scenario.

Figure 42. 2050 Achievable Natural Gas Demand Impact Potential by Zone Compared to Baseline Demand, Site Incentive and Carbon Price+ Scenarios

Achievable natural gas peak demand reduction potential in 2050 by NYISO zone, compared to baseline natural gas peak demand, Site Incentive and Carbon Price+ Scenarios



NYISO zone	West	Central	Long Island	Capital	NYC	Hudson Valley	Genesee	Mohawk Valley	Dun-woodie	North	Mill-wood
2050 baseline (MMBtu-day)	48,568	38,620	35,462	33,582	29,506	17,576	15,504	15,250	6,306	3,362	1,257
Site Incentive as a % of 2050 baseline	34%	39%	38%	23%	28%	39%	44%	32%	37%	46%	40%
Carbon Price+ as a % of 2050 baseline	38%	44%	34%	21%	33%	41%	41%	41%	44%	37%	52%

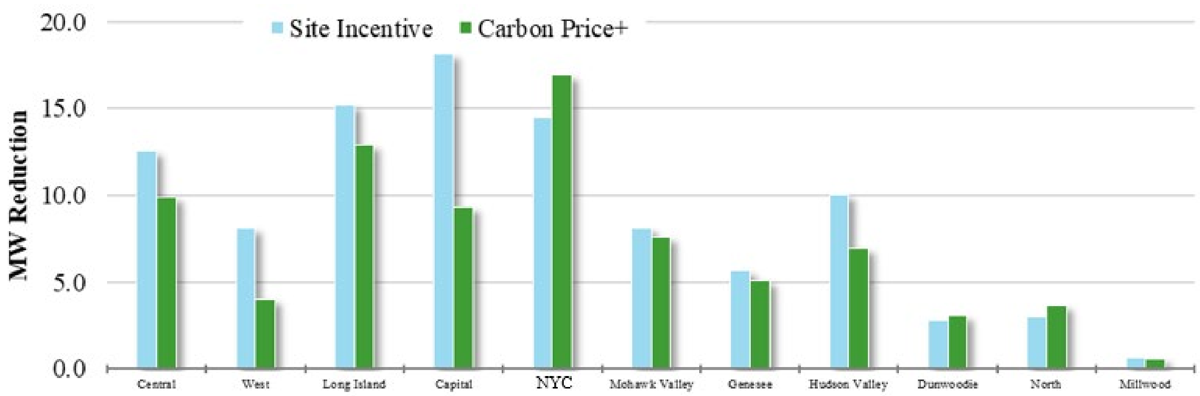
Regional electric demand potential does not follow the pattern seen in baseline demand by zone, and the results vary notably between the two scenarios and regions (Figure 43). While the West contributes 18% to base peak demand, it accounts for only 8% of savings in the Site Incentive scenario and 5% of savings in the Carbon Price+ scenario. In contrast, Long Island, Capital, and New York City together represent 37% of peak demand combined and almost 50% of peak demand savings in each scenario.

In the Site Incentive scenario, percent savings over baseline in the 2050 range from 2% in the West zone to 8% in the North. For the Carbon Price+ scenario, demand savings range from 1% in the West to 10% in the North. The differences stem from how each scenario's potential varies by category and interacts with the differing subsector mix across zones. The Carbon Price+ scenario derives most of its additional savings from electrification and CCUS, which increase electricity use, but this is not uniform across subsectors or zones.

While the Carbon Price+ scenario shows less demand savings statewide, most of those savings occur in zones with either a large share of base use in the Chemical subsector (which gets the biggest boost in carbon and energy savings between Site Incentive and Carbon Price+ scenarios) or has CCUS adoption in the Carbon Price+ scenario, or both.

Figure 43. 2050 Achievable Electric Demand Impact Potential by Zone Compared to Baseline Demand, Site Incentive and Carbon Price+ Scenarios

Achievable electric peak demand reduction potential in 2050 by NYISO zone, compared to baseline demand, Site Incentive scenario, and Carbon Price+ scenario.



NYISO zone	Central	West	Long Island	Capital	NYC	Mohawk Valley	Genesee	Hudson Valley	Dun-woodie	North	Mill-wood
2050 baseline (MW)	431	406	316	307	239	231	170	160	51	38	10
Site Incentive as a % of 2050 baseline	2%	3%	5%	6%	6%	4%	3%	5%	5%	8%	6%
Carbon Price+ as a % of 2050 baseline	1%	2%	4%	3%	7%	3%	3%	5%	6%	10%	6%

Table 6 illustrates the pattern of demand savings potential over time by zone, in this case for the Site Incentive scenario.

Table 6. Achievable Peak Demand Reduction Potential by Fuel and Zone, Site Incentive Scenario

Metric/Scenario	2027	2030	2040	2050
Electric peak demand reduction (MW)				
Central	0.0	0.5	5.5	12.5
West	-1.0	-1.6	1.3	8.1
Long Island	0.6	1.7	7.7	15.2
Capital	0.9	2.5	10.2	18.2
New York City	0.1	0.7	5.5	14.5
Mohawk Valley	0.5	1.2	4.8	8.1
Genesee	0.2	0.5	2.9	5.7
Hudson Valley	0.6	1.5	5.5	10.1
Dunwoodie	0.1	0.2	1.1	2.8
North	0.2	0.5	1.6	3.0
Milwood	0.0	0.1	0.3	0.6
Total peak demand reduction (MW)	**2.1**	**7.8**	**46.4**	**98.9**
Natural gas peak demand reduction (MMBtu-day)				
Central	17,415	36,226	85,838	123,967
West	18,917	39,385	92,974	133,792
Long Island	44,702	92,821	224,718	329,594
Capital	5,781	12,049	27,540	38,618
New York City	9,251	19,238	44,517	63,210
Mohawk Valley	19,703	40,921	98,872	144,831
Genesee	18,315	38,040	92,012	134,864
Hudson Valley	15,779	32,762	79,051	115,676
Dunwoodie	1,072	2,238	5,046	7,007
North	6,020	12,492	30,336	44,621
Milwood	89	186	387	497
Total peak demand reduction (MMBtu-day)	**157,043**	**326,358**	**781,290**	**1,136,677**

3.4 Highest Savings Measures

Table 7 reports the top energy-saving measures in 2030, along with their projected 2050 savings potential, for the Site Incentive and Carbon Price+ scenarios, the lowest and highest adoption scenarios modelled. The measures shown and their ordering are based on 2030 emissions savings, which means some of 2050's top 10 measures may not appear in the list.

Focusing on the top measures in 2030 highlights actions that are both technically feasible and have high near-term potential. In contrast, the 2050 forecast may forecast higher potential for emerging technologies, but with increased uncertainty due to the longer time horizon.

Table 8 shows the top 10 measures ranked by emissions reduction for both scenarios.

Table 7. Top 10 Measures Ranked by 2030 Energy Savings in Site Incentive and Carbon Price+ Scenarios

Scenario	Measure	2030 potential (million MMBtu)	2050 potential (million MMBtu)
Site Incentive	Electric Infrared Processing	5.2	11.4
Site Incentive	Process Heat Recovery	1.6	2.8
Site Incentive	Process Heating Insulate Equipment	0.6	1.6
Site Incentive	CHP, Gas Reciprocating Engine (L/M Temp)	0.3	1.6
Site Incentive	Improved Process Controls	0.3	0.9
Site Incentive	CHP, Gas Turbine (L/M Temp)	0.3	2.4
Site Incentive	Refrigeration, System Upgrade	0.3	0.5
Site Incentive	Microwave or RF Processing	0.3	0.5
Site Incentive	Dust Collection System, Fan ASD	0.2	0.7
Site Incentive	Induction Furnace	0.2	0.8
Site Incentive	**Top 10 Cumulative Annual Potential**	**9.3**	**23.3**
Carbon Price+	Electric IR Processing	6.8	12.1
Carbon Price+	Process Heat Recovery	1.8	2.9
Carbon Price+	Process Heating, Insulate Equipment	0.8	1.7
Carbon Price+	CHP, Gas Reciprocating Engine (L/M Temp)	0.7	2.6
Carbon Price+	IR, Gas Turbine (L/M Temp)	0.6	3.5
Carbon Price+	Improved Process Controls	0.5	0.9
Carbon Price+	Process Heat Pump	0.4	3.0
Carbon Price+	Dust Collection System, Fan ASD	0.4	0.8
Carbon Price+	Refrigeration, System Upgrade	0.3	0.5
Carbon Price+	Microwave or RF Processing	0.3	0.4
Carbon Price+	**Top 10 Cumulative Annual Potential**	**12.4**	**28.4**

Table 8. Top 10 Measures Ranked by 2030 Emissions Reduction Potential in Site Incentive and Carbon Price+ Scenarios

Scenario	Measure	2030 achievable potential (thousand $MTCO_2e$)	2050 achievable potential (thousand $MTCO_2e$)
Site Incentive	Electric Infrared Processing	530	1,339
Site Incentive	Process Heat Recovery	148	245
Site Incentive	Process Heating, Insulate Equipment	53	139
Site Incentive	Microwave or RF Processing	26	52
Site Incentive	CHP, Gas Reciprocating Engine (L/M Temp)	25	32
Site Incentive	Improved Process Controls	21	56
Site Incentive	Process Heat Pump	21	142
Site Incentive	CHP, Gas Turbine (L/M Temp)	21	60
Site Incentive	Pulsed Electric Field	20	46
Site Incentive	Induction Furnace	20	76
Site Incentive	**Top 10 Cumulative Annual Potential**	**884**	**2,187**
Carbon Price+	Electric IR Processing	688	1,419
Carbon Price+	Process Heat Recovery	168	248
Carbon Price+	Process Heating, Insulate Equipment	74	147
Carbon Price+	CHP, Gas Reciprocating Engine (L/M Temp)	51	50
Carbon Price+	Process Heat Pump	43	429
Carbon Price+	CHP, Gas Turbine (L/M Temp)	42	87
Carbon Price+	Improved Process Controls	29	58
Carbon Price+	Microwave or RF Processing	25	41
Carbon Price+	Solar Thermal Storage System	24	221
Carbon Price+	Dust Collection System, Fan ASD	24	0
Carbon Price+	**Top 10 Cumulative Annual Potential**	**1,168**	**2,701**

The majority of the top measures are process heating end-use measures, with process heat recovery ranking among the top measures for both energy and emissions savings in both scenarios. More than two-thirds of the decarbonization potential from the top 10 measures comes from electrification technologies, while the remaining measures are all forms of energy efficiency interventions.

The leading measure in both scenarios is electric infrared processing, an electrification measure considered an established electrotechnology with minimal integration challenges, comparable to electric boilers (Ashabi et al. 2025). Process heat recovery systems vary by subsector, but generally include technologies such as preheating combustion air, heat pumps, and mechanical vapor recompression.

Solar Thermal Storage System for process heat is included in the top 10 measures for the Carbon Price+ scenario. This measure assumes that an industrial site installs a concentrated solar power (CSP) system with thermal energy storage to produce steam or direct process heat for temperatures up to 400 degrees Celsius (^{o}C). In this system, concentrated solar energy is used either directly to produce hot water or steam, or indirectly by heating a heat-transfer fluid, which is then used to deliver heat where needed.

3.5 Potential Estimates in Context

Table 9 summarizes the corresponding energy results for all levels of the decarbonization potential. While technical potential for emissions reduction benefits from low-carbon fuels and CCUS, these categories do not produce energy savings. As a result, energy savings as a percent of baseline are significantly lower than for emissions savings. The gap between carbon and energy percent savings is smallest for the Site Incentive and Carbon Price scenarios, which have little to no savings from low-carbon fuels or CCUS.

Table 9. Statewide Summary of 2050 Energy Savings Potential by Scenario

Energy savings compared to baseline energy use, measured in MMBtu.

Metric/Scenario	2027	2030	2040	2050
Baseline consumption (million MMBtu)	**176**	**178**	**186**	**201**
Cumulative savings (million MMBtu)				
Technical potential	20	30	40	41
Economic potential, HiCO_2Value	15	23	40	52
Economic potential, LoCO_2Value	15	23	39	52
Carbon Price+ Scenario	8	16	32	42
Carbon Price Scenario	7	14	29	37
Site Incentive Scenario	6	12	25	32
Savings as % of baseline				
Technical potential	11%	17%	21%	21%
Economic potential, HiCO_2Value	8%	13%	21%	26%
Economic potential, LoCO_2Value	8%	13%	21%	26%
Carbon Price+ scenario	5%	9%	17%	21%
Carbon Price scenario	4%	8%	15%	19%
Site Incentive scenario	3%	7%	13%	16%

Table 10 summarizes the decarbonization potential for the technical, economic, and three adoption scenarios, and compares them to baseline emissions in select years. By 2050, the highest adoption scenario achieves a 30% reduction from baseline emissions, about 76% of economic potential in the LoCO_2Value case.

Table 10. Statewide Summary of Statewide Decarbonization Potential Estimates

Metric/Scenario	2027	2030	2040	2050
Baseline emissions (thousand $MTCO_2e$)	18,175	15,981	13,123	13,921
Cumulative reductions (thousand $MTCO_2e$)				
Technical potential	2,361	3,531	7,193	9,659
Economic potential, HiCO2Value	1,545	2,144	3,859	6,730
Economic potential, LoCO2Value	1,509	2,075	3,466	5,536
Carbon Price+ Scenario	753	1,499	3,051	4,208
Carbon Price Scenario	706	1,332	2,588	3,381
Site Incentive Scenario	532	1,130	2,296	2,890
Reductions as % of baseline				
Technical potential	13%	22%	55%	69%
Economic potential, HiCO2Value	9%	13%	29%	48%
Economic potential, LoCO2Value	8%	13%	26%	40%
Carbon Price+ Scenario	4%	9%	23%	30%
Carbon Price Scenario	4%	8%	20%	24%
Site Incentive Scenario	3%	7%	17%	21%

3.6 Conclusions

The Industrial sector in New York State presents significant potential for energy savings and GHG emissions reductions. By 2050, the sector's technical potential includes a 21% reduction in energy use and a 69% reduction in GHG emissions compared to their respective baseline projections. The economic potential reaches 26% for energy savings and 40% to 48% for emissions reductions, depending on the societal value assigned to carbon reductions.

Economic energy savings potential is, counterintuitively, higher than technical potential. This is due to differences in the mix of measures included in each case. Economic potential relies more heavily on energy efficiency, while technical potential includes a greater share of measures that are energy neutral (such as hydrogen) or increase energy use (such as CCUS). As a result, economic energy savings reach 26% of the 2050 baseline, compared to 21% energy savings associated with the technical potential. Achievable potential across various scenarios ranges from 16% to 21% of energy savings, corresponding to 21% to 30% in emissions reductions by 2050. Also note that the team may be undercounting potential because of undefined end uses (see discussion in Section 2 on End Use Not Reported).

Electrification is the largest source of achievable energy savings and decarbonization potential in New York State's Industrial sector throughout the forecast. Currently, many drying and curing processes, including infrared, induction, microwave, and ultraviolet drying and curing, offer cost-effective electrification opportunities. In 2025, more than half of the energy savings potential comes from electrification. Similarly, more than half of the energy emissions reduction potential in 2025 comes from electrification, rising to more than two-thirds by 2030. In 2050, across all adoption scenarios, electrification accounts for at least 55% of energy savings and 75% of decarbonization potential.

Energy efficiency contributes a larger share of energy savings than emission reductions in 2030 and beyond. In 2025, 2030, and 2050, energy efficiency accounts for at least 42%, 40%, and 41% of energy savings potential across all adoption scenarios. In 2025, 2030, and 2050, energy efficiency accounts for at least 45%, 35%, and 18% of decarbonization potential, respectively, across all adoption scenarios. The study assumes that the electric grid will meet the 2040 Climate Act targets, which, over time, decreases the emissions savings from energy efficiency measures for electricity.

Low-carbon fuels (via green hydrogen) lead to technical decarbonization potential in 2050, but have modest economic potential and limited achievable potential. The technical decarbonization potential exists for green hydrogen to replace fuel oils and act as a chemical feedstock, but only 10% of this potential is economic, making low-carbon fuels the lowest of the four categories of measures. The absence of low-carbon fuels accounts for most of the difference between the technical and economic emissions reduction potential. While low-carbon fuels have long-term technical potential, their costs significantly reduce economic and achievable potential.

All low-carbon fuels adopted were green hydrogen, all of which replaced base petroleum use. Green hydrogen is cost-effective from a societal standpoint as a replacement for some petroleum and coal use, but not for natural gas. Avoided costs for green hydrogen include substantial health benefits from replacing oil and coal, which have dramatically higher health impacts than natural gas. RNG was modelled only as a direct replacement for natural gas without a change in equipment and was not economical in any application. Blue hydrogen was modelled in the Phase One potential study, but was never chosen over green hydrogen; therefore, this Phase Two study did not model it.

CCUS contributes significantly to the economic decarbonization potential in 2050, but has limited achievable potential. CCUS accounts for 29% of economic potential in 2050, roughly matching its share of technical potential. Among the adoption scenarios, only the Carbon Price+ scenario shows more than negligible CCUS savings, representing 6% of emissions reduction potential in 2050; this assumes public investment in infrastructure dramatically reduces barriers to CCUS adoption.

By end use, process heating contributes the greatest energy savings and decarbonization potential. These savings come primarily from natural gas efficiency and electrification and make up more than 70% of potential in the adoption scenarios. Low- and medium-temperature processes have greater savings potential than high-temperature processes and make up 90% of process heat decarbonization potential. Food, Transportation Equipment, and Fabricated Metals have the largest portion of low- and medium-temperature process heating energy. The cement industry's high-temperature process heat requires breakthrough technologies to electrify. Facility HVAC and Boilers contribute smaller but still notable energy savings and decarbonization potential.

The Chemicals, Food, and Other subsectors contributed the most to achievable energy savings. Together, these three subsectors account for 53% to 55% of energy savings potential in the adoption scenarios. Chemicals and Food are the two largest contributors (37% to 38% of the total).

The Chemicals, Transportation Equipment, and Food subsectors contributed the most to achievable emissions savings. Chemicals and Food are the two largest contributors to energy efficiency potential in all adoption scenarios (together, 44% to 45% of the total). For electrification, Chemicals and Transportation Equipment together make up 37% of potential in the Carbon Price+ scenario, while Transportation Equipment and Food take the top two spots in the other two scenarios (35% to 37%). Low-carbon fuels' potential is highest in the Transportation Equipment and Non-Metallic Minerals subsectors (47%) for the Carbon Price scenario, while Transportation Equipment and Food take the top spots in the Carbon Price+ scenario (52%). Chemicals accounts for 99% of CCUS savings in the two Carbon Price scenarios. The Site Incentive scenario shows no low-carbon fuel or CCUS savings.

Key measures for near-term energy savings and emissions reductions include process heat electrification measures, process heat recovery, and combined heat and power (CHP). Process heat electrification offers promising savings on the energy and emissions front that will increase as the grid decarbonizes. These measures include electric infrared (IR) processing, microwave or radio frequency (RF) processing, and process heat pumps. While CHP often receives less attention than electrification as an energy-saving and decarbonization measure, it offers near-term potential for high-temperature boilers and could switch to hydrogen in the long term.

While emission reductions from electricity energy-efficiency measures decline over time as the grid decarbonizes, these measures continue to contribute significantly to energy savings potential. Increased electrification across all New York State sectors means these measures will remain important for managing electrical load. Without implementing energy efficiency measures, decarbonization in the Industrial sector would increase energy demand by over 200 megawatts (MW). Continued investment in electric energy efficiency can more than offset this increase and produce a small overall net demand reduction.

Regional energy savings and decarbonization potential largely correlate with baseline emissions but also depend on the mix of industrial subsectors. The West zone has the largest base energy use and emissions, as well as the highest achievable potential of all the zones. In most zones, percent emissions savings exceed percent energy savings. The West and Central zone together account for 34% of base emissions and 35% to 36% of emissions reduction potential. Dunwoodie, with a prevalence of subsectors with high potential, has the highest emissions reduction potential by percent savings. Still, as one of the smallest zones by base use, its absolute contribution is small. The Capital zone has the second-largest base emissions, but ranks fifth for achievable potential in the Site Incentive scenario and third in the Carbon Price+ scenario. Capital's largest subsectors are Paper, with a relatively low potential in both scenarios, and Chemicals, with below-average potential in the Site Incentive scenario only.

Industrial decarbonization potential is associated with smaller percent reductions in energy use. Not all decarbonization measures reduce energy use; in fact, CCUS and thermal storage increase it. The decarbonization technical potential found in this study corresponds to a 21% reduction in energy use in 2050, while economic potential, which draws a larger share of its carbon savings from energy efficiency, is associated with a 26% reduction in energy use. The adoption scenarios range from 16% to 21% energy savings.

Estimating potential in the industrial sector requires a deep and detailed approach. Identifying energy savings and decarbonization opportunities, particularly for electrification, requires a granular understanding of the energy consumption for each subsector and its processes. Attention to emerging technologies like solar thermal energy and thermal energy storage, along with advances in technologies such as CHP and process heat pumps, creates a larger technical and achievable potential opportunity for energy savings and decarbonization.

4 Overview of Methods

This section provides an overview of the methodology used to estimate the energy and decarbonization potential in New York State's Industrial sector. Appendix A provides additional details.

4.1 Segmentation Approach

The study team examined the energy and decarbonization potential by industrial segments defined by the combination of industry subsector (three-digit North American Industry Classification System [NAICS] code), energy expenditure tier, presence of DACs, and NYISO zone (see Table 11). The recently completed "Stock Study" defined the first three characteristics. The "Stock Study" explicitly breaks out eight manufacturing NAICS groups individually and assesses measures specific to each. The remaining manufacturing NAICS groups are modelled as a single subsector: the Other category. The study team assessed the potential in the Other category for broadly applicable industrial measures but not for industry-specific process measures.

Table 11. Study Segmentation

Industrial Subsector (3-digit NAICS[a])	Annual Energy Expenditure Tier	NYISO Zone	DAC
Paper Primary Metals Non-Metallic Minerals Chemicals Food Fabricated Metals Transportation Equipment Computers and Electronics Other[b]	Tier 1: $1,000,000 and above Tier 2: $500,001–$999,999 Tier 3: less than $500,000	A West B Genessee C Central D North E Mohawk Valley F Capital G Hudson Valley H Millwood I Dunwoodie J New York City K Long Island	Within a 3-mile radius of a DAC or outside that radius

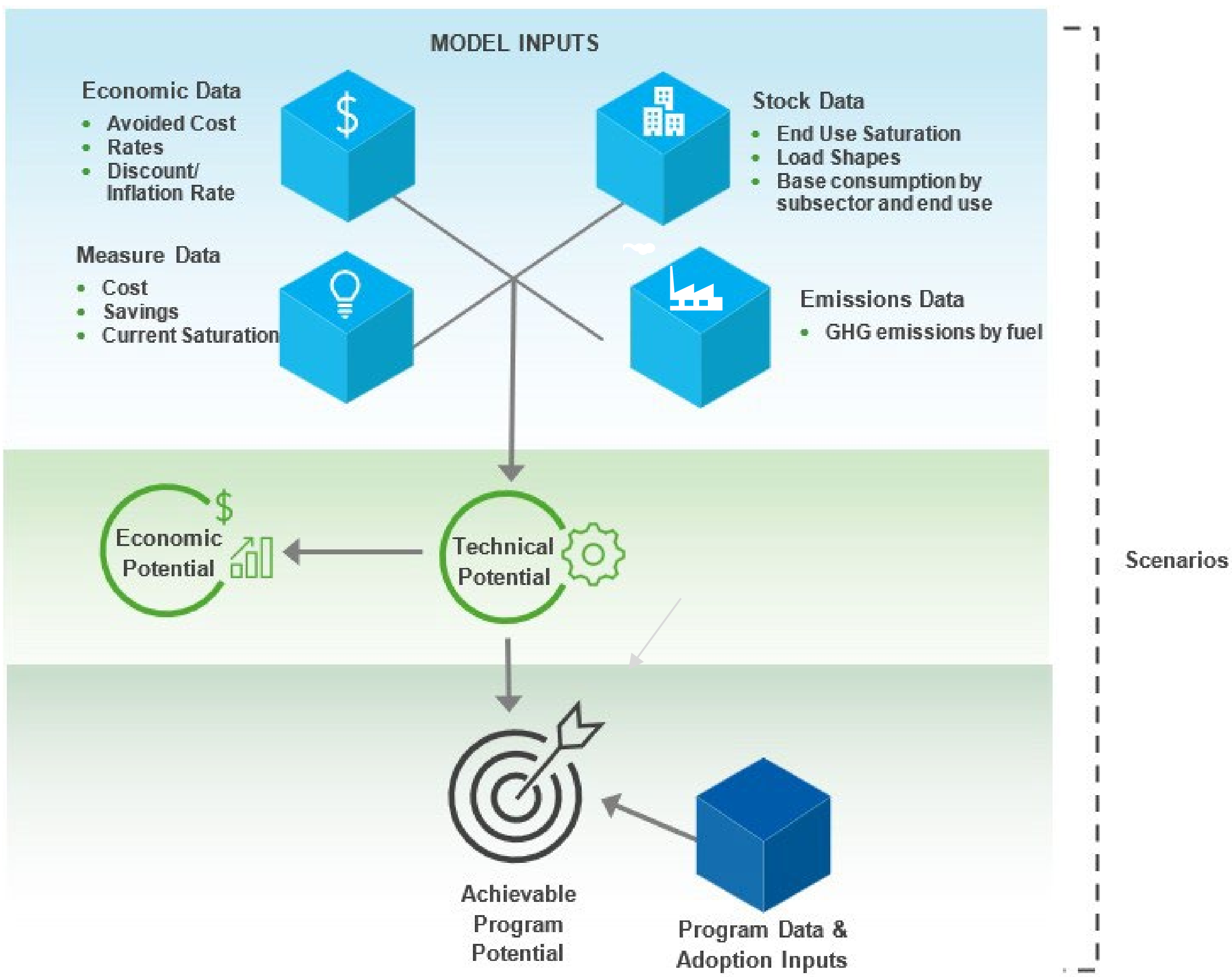
[a] NAICS is the North American Industry Classification System, a widely used system for classifying of business establishments.
[b] The Other category includes Petroleum, Beverage/Tobacco, Wood Products, Plastics/Rubber, Electrical Equipment, Machinery, Printing, Apparel, Leather, and Miscellaneous Manufacturing.

Figure 34 presents a map of the NYISO zones. NYISO identifies its zones by both name and letter, with the zone letters assigned geographically, broadly west to east and north to south.

4.2 Modelling Overview

The energy and decarbonization potential modelling system involves several systematic analytical steps to estimate the effects of energy efficiency, electrification, low-carbon fuels, and CCUS measures on system load and GHG emissions. The study team builds these estimates from the bottom up, matching energy-intensive industrial processes or equipment with alternative, low-emission technologies, and enacting these investments when they make sense for society economically (economic potential only) or the facility owner financially (achievable potential only). Figure 44 presents a simplified overview of these basic analytical steps and key inputs.

Figure 44. Simplified Conceptual Overview of Modelling Process for Estimating Potentials



The first stage in the process (top section of the figure) develops the inputs necessary to model energy and decarbonization potential. This stage includes the critical step of creating the list of measures to model. Section 4.3 discusses data development for the four categories in Figure 44. Once developed, the study team uses this data to populate the energy and decarbonization potential model.

The team uses a series of Excel spreadsheets to store inputs or perform calculations for estimating potential. Appendix A describes the model and its analytical steps in detail. The initial modelling uses NYS and EIA inputs and reflects the team's best forecasts of the future trajectory of technology costs, rates, avoided costs, fuel availability, carbon emissions from electricity, programs, and policy. The team then explores alternative scenarios, such as savings potential under different future cost trajectories or policies.

4.3 Data Development

The team developed input data through the following steps:

1. Collected economic data, including avoided costs, cost of carbon, electric rates, forecasted fuel prices, discount rates (societal and customer), inflation rate, line losses, and leakage rates. Appendix A provides these inputs. To the extent possible, the team aligned these values with other NYS analyses, such as the "Assessment of Energy Efficiency and Electrification Potential in New York State Residential and Commercial Buildings" decarbonization potential study (NYSERDA 2023b) and *New York State Climate Action Council Scoping Plan* (NYSERDA 2022a).
2. Reviewed industrial stock and baseline equipment data from the "Stock Study", then analyzed and developed information on industry characteristics by market segment. This included market size (as total all-fuels energy consumption), energy consumption and intensity by end use, load patterns by time of day and year (i.e., load shapes), stock shares of key energy-consuming equipment, and stock shares of energy efficiency technologies and practices. Segmentation captured consumption by industry subsector, expenditure tier, NYISO zone, and DAC proximity. Appendix A further describes the baseline data.
3. Gathered and developed emissions data to account for in-state and upstream greenhouse GHG emissions from fuel combustion within New York State's Industrial sector. Data includes CO_2, nitrous oxide (N_2O), and methane (CH_4) emissions factors by fuel, with time-varying emissions factors for electricity.
4. Developed a list of industrial decarbonization measure opportunities. The team developed an initial draft and provided it to NYSERDA and stakeholders. The final measure list incorporated their comments.

5. Gathered and developed measure data to characterize measures and the baseline equipment or conditions to which they apply, including savings parameters (as a percent of baseline equipment consumption), costs, and expected useful life. Appendix A provides measure descriptions and input details.

The study team looked at measures and interventions across a range of industrial end uses, based on EIA's MECS categorization. Table 12 shows the 13 industrial end uses.

Table 12. Industrial End Uses Defined by the Manufacturing Energy Consumption Survey

Source: EIA MECS (N.d.).

Process	Nonprocess	Generation/Cogeneration
Conventional Boiler Use	Facility HVAC	Combined Heat and Power and/or Cogeneration Process
Process Heating	Facility Lighting	Conventional Electricity Generation
Process Cooling and Refrigeration	Other Facility Support	
Machine Drive	On-site Transportation	
Electro-Chemical Processes	Other Non-process Use	
Other Process Use		

The study team categorized existing and emerging measures across sectors, end uses, and the four decarbonization categories listed above and defined in the *DOE Industrial Decarbonization Roadmap* (2022):

- **Energy Efficiency**
  Energy efficiency refers to activities or technology investments that enable a facility to reduce or better manage energy consumption at the facility or system level. This included improving the performance of industrial processes, optimizing thermal heat from manufacturing processes, and using advanced data analytics to increase energy productivity in manufacturing processes. Reducing the energy consumption reduces GHG emissions associated with fossil fuel combustion in the Industrial sector.
- **Electrification**
  Electrification involves switching fossil-fuel-consuming equipment with an equivalent, efficient electrotechnology. This includes the electrification of process heat, electrification of facility space heating, or replacing thermally driven processes with electrochemical ones. Electrification reduces industrial emissions from on-site combustion of fossil fuels.
- **Low-Carbon Fuels**
  The substitution of low-carbon fuels, feedstocks, and energy sources, such as hydrogen or biofuels, can further reduce combustion-associated GHG emissions for industrial processes. Low-carbon fuels are especially relevant for high-temperature process heating that is challenging to electrify. This study focuses on green hydrogen and renewable natural gas when examining the decarbonization potential of low-carbon fuels.

- **CCUS**
  Capturing generated CO_2 before it can enter the atmosphere, using captured CO_2 wherever possible, and storing captured CO_2 long-term. CCUS is a key strategy for mitigating hard-to-abate emissions sources.

Appendix A details measure data elements.

4.4 Data Application

This section discusses how the study applied the above data types.

4.4.1 Data Application for Baseline Characterization

To estimate energy and decarbonization savings potential, the team first needed to understand current energy use and equipment. The team began by segmenting New York State's Industrial sector using the "Stock Study", which relied on surveys and site visits to assess firmographics, location, DAC proximity, energy use, and clean energy opportunities to characterize New York State's industrial sector. Table 13 shows the segmentation used in this study.

Table 13. Overview of Industrial Analysis Segmentation

Dimension	Segmentation Variable	Description
1	Subsector	Industry classification using three-digit NAICS code: Chemicals, Computer and Electronics, Food, Non-Metallic Minerals, Paper, Transportation Equipment, Fabricated Metals, Primary Metals, and Other
2	Expenditure Tier	Annual energy expenditure range: ▪ Tier 1 ($1,000,000+) ▪ Tier 2 ($500,001–$999,999) ▪ Tier 3 (less than $500,000)
3	NYISO Zones	West, Genesee, Central, North, Mohawk Valley, Capital, Hudson Valley, Milwood, Dunwoodie, New York City, Long Island
4	DAC	Whether or not an industrial facility is located within 3 miles of a DAC

To develop the baseline characterization for each segment, the study team took the following steps:

1. Developed base year (2023) market size (defined as all-fuels MMBtu consumption by segment) and annual energy use for each market segment using the "Stock Study" data.
2. Used the "Stock Study" and secondary sources[9] to develop base equipment saturations, equipment characteristics, and process characteristics (e.g., average temperature of a process heating process), breaking out baseline consumption by fuel type, end use, and base equipment.
3. Calibrated annual energy use in each segment to base year values.

4. Compared and cross-checked data with other recent contractor studies and internal subject matter experts.
5. Collaborated with NYSERDA and stakeholders to vet data against their knowledge and experience.

This baseline characterization allowed the study team to determine annual energy use and intensity for each market segment.

4.4.2 Data Application for Estimating Measure Potential Impacts

The study team calculated measure potential for each industrial segment (based on the segmentation described earlier) for the core scenarios and aggregated these results to estimate statewide potentials.

In this bottom-up modelling approach, the study team first estimated the technical potential for energy savings by integrating the market segment parameters developed in the baseline characterization and the following decarbonization measure data inputs:

1. **Equipment lifetime estimates,** in years: A measure or equipment's useful life. The team models equipment replacements according to their measure life.
2. **Measure saturation:** The fraction of baseline equipment already converted to the decarbonization measure. Depending on the characteristics and specificity of the baseline equipment, the not-complete factor could be 0%. This applies to all electrification measures, for example.
3. **Feasibility factor:** The fraction of baseline equipment for which the carbon reduction measure is technically feasible from an engineering perspective. Because the study team broadly defines base equipment and measures in many cases, not every facility with the base equipment can implement the measure. For example, infrared drying is not feasible for all drying applications in the food industry. This factor is designed to capture factors' feasibility limitations beyond those addressed in the other factors.
4. **Savings factor:** The percent reduction in baseline end-use energy consumption or GHG emissions for the fuel impact being calculated, resulting from application of the measure. For energy efficiency measures, the savings factor refers to the percentage reduction in baseline equipment energy consumption for the fuel savings being calculated, resulting from the application of the efficient technology.
5. **CO_2 emissions factor:** The CO_2 emissions per unit of energy savings (MMBtu or kilowatt-hours [kWh]). If the team models electricity emissions hourly, this factor incorporates the savings load shape for the measure.

Economic: Incremental measure costs of each decarbonization measure are compared to the energy and carbon savings delivered by the measure over its lifetime to produce estimates of decarbonization impacts per unit of additional cost.

5 References

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Appendix A. Detailed Methodology

A.1 Stock and Baseline Data Development

The "Stock Study" provided the foundation for estimating savings potential. It collected detailed information on industrial facilities, using web and phone surveys of more than 600 facilities and on-site visits to more than 100 facilities. The team used the Manufacturing End Use Consumption Survey (MECS) data to provide additional resolution where needed, for example, to break out nonelectric fuel use into specific fuels. Additionally, the "Stock Study" examined industrial facility firmographics, location, proximity to DACs, and energy use to inform the study's geographic analysis. The study's geographic analysis geocodes[10] the majority (97.5%) of manufacturing facilities in the State.

The study team adapted the "Stock Study" data to align with the segmentation in this study.

- The 13 specific subsectors were mapped directly from the "Stock Study" to this study. The team aggregated the remaining 13 subsectors broken out in the "Stock Study" into a single "Other" category for this study.
- The "Stock Study" assessed facilities by three expenditure tiers, which the study team incorporated into the potential analysis without changes.
- The "Stock Study" geocoding enabled the team to readily map facilities and associated data to New York Independent System Operator (NYISO) zones.
- The "Stock Study" assessed facilities for proximity to a DAC using a 3-mile radius, which the study team adopted for this study.

The "Stock Study" breaks out consumption into end uses using 2018 MECS results (see Figure 1). While this breakout was a useful first cut at describing how energy is being used, the study team refined these into more granular processes or equipment to identify specific opportunities for savings. Because the measure list includes specific technologies (e.g., induction, infrared) that can replace conventional drying technologies. The study team separated drying from the broader process heating category.

The study team drew on a large body of research on process energy use within specific industries and pulled from these secondary sources to create the breakouts necessary to support the study analysis.

The study team ensured that the disaggregated (end use/equipment type) consumption adds up to top-line consumption by subsector, tier, zone, and DAC proximity.

The study team finalized baseline equipment inputs by incorporating end-use load shapes and estimating demand impacts for both electricity and natural gas.

A.2 Measure Data Development

Measure data required to estimate savings potential included:

- Measure cost (equipment, labor)
- Nonenergy impacts (NEIs) to the facility, including operations and maintenance (O&M) expenses
- Factors to convert costs to cost per unit of base consumption; for example, if chiller costs are entered per ton, the factor will convert them to $/baseline all-fuels million British thermal units (MMBtu)
- Expected useful life (EUL)
- Implementation type (retrofit, replace-on-burnout, early replacement, new)
- Measure savings (percent of baseline equipment consumption)
- For fuel-switching measures, switched-to fuel added per MMBtu of switched-from fuel saved
- Current measure market penetration
- Codes and standards information to inform changes to baseline efficiency over time

These inputs varied by measure and by subsector, zone, or forecast year. Table A-1 summarizes how inputs vary across these model elements.

Table A-1. Input Variation by Measure, Subsector, Region, and Forecast Year

Measure Input	Varies By			
	Measure	**Subsector**	**Zone**	**Forecast Year**
Measure cost	X			X
NEIs	X	X		X
Cost conversion factor	X	X		
EUL	X			
Implementation type	X			
Measure savings	X		HVAC only	
Current measure market penetration	X	X		[a]
Codes and standards	X			X

[a] The model uses the initial market penetration as an input and calculates changes over the forecast horizon based on stock turnover and adoption modelling.

A.3 Secondary Research and Leveraging Data Sources

The study team leveraged multiple data sources. In the cases where similar data was available from two sources, they prioritized the source that best represents New York State. Table A-2 presents the hierarchy that the study team used to systematically inventory data sources in developing the measure list. The study team followed the same protocol for measure parameter development.

Table A-2. Potential Study Measure Data Source Hierarchy

Priority	Source	Details
1	NYSERDA	Project reports, technical studies, and baseline assessments specific to NYS
2	Regional TRM and site-specific data	Internal data from DNV and Antares based on regional audits, site studies, and NYS TRM
3	DOE sources	National white papers and tools from LBNL, ENERGY STAR industry guides, and the IAC database
4	Contractor industrial practice data and technical research	Subject matter expertise, literature reviews, and nonregional site-specific data
5	Well-vetted nonregional sources	References such as the Illinois TRM and data from the Northwest Power and Conservation Council

Table A-3 presents an initial list of sources that the team used to develop the measure list and/or identified as a data source to define measure parameters. The team organized these sources by priority, following the hierarchy outlined in Table A-2. Key measure parameters required for model characterization include savings, costs, equipment lifetime, and baseline definition. An “x” in the parameter column indicates that the source provides data for that specific parameter.

Table A-3. Initial List of Measure Data Sources

Source Name	Savings	Costs	Lifetime	Baseline
Priority 1				
New York State Energy Research and Development Authority (NYSERDA). 2017. "Industrial Facilities Stock Assessment: Phase One." Albany, NY: NYSERDA.	x			x
New York State Energy Research and Development Authority (NYSERDA). 2017. "Industrial Facilities Stock Assessment: Phase Two." Albany, NY: NYSERDA.	x			x
New York State Energy Research and Development Authority (NYSERDA). 2020. "Improving Industrial Efficiency, Computer and Electronics Info Sheet." Albany, NY: NYSERDA.	x			x
New York State Energy Research and Development Authority (NYSERDA). 2020. "Improving Industrial Efficiency, Fabricated Metals Info Sheet." Albany, NY: NYSERDA.	x			x
New York State Energy Research and Development Authority (NYSERDA). 2020. "Improving Industrial Efficiency, Plastics and Rubber Products Info Sheet." Albany, NY: NYSERDA.	x			x
New York State Energy Research and Development Authority (NYSERDA). 2020. "Improving Industrial Efficiency, Chemical Manufacturing Info Sheet." Albany, NY: NYSERDA.	x			x
New York State Energy Research and Development Authority (NYSERDA). 2020. "Improving Industrial Efficiency, Food Manufacturing Info Sheet." Albany, NY: NYSERDA.	x			x
New York State Energy Research and Development Authority (NYSERDA). 2020. "Improving Industrial Efficiency, Primary Metals Info Sheet." Albany, NY: NYSERDA.	x			x
New York State Energy Research and Development Authority (NYSERDA). 2020. "Improving Industrial Efficiency, Non-Metallic Minerals Info Sheet." Albany, NY: NYSERDA.	x			x
New York State Energy Research and Development Authority (NYSERDA). 2020. "Improving Industrial Efficiency, Pulp and Paper Info Sheet." Albany, NY: NYSERDA.	x			x
Priority 2				
Antares. 2018. ECM Identification Using Site-Specific Data and DOE Save Energy Now Tools. Internal report for NYSERDA. Antares. 2023. New York On-Site or Site-Specific Data. Internal report.	x	x		x
DNV. 2019. "New York Site-Specific Industrial Audit Data". Internal dataset.	x	x		x
New York State Energy Research and Development Authority (NYSERDA). 2021. *DOE ITP Save Energy Now.* Albany, NY: NYSERDA.	x	x		x
New York State Energy Research and Development Authority (NYSERDA). 2022. *IPE Non-Natural Gas Fossil Fuel ECM Identification.* Albany, NY: NYSERDA.	x	x		x
New York State Energy Research and Development Authority (NYSERDA). 2022. *New York State Technical Resource Manual Version 9.* Albany, NY: NYSERDA.	x		x	x

Table A-3. (continued)

Source Name	Savings	Costs	Lifetime	Baseline
Priority 3				
Worrell, Ernst, Paul Blinde, Maarten Neelis, Erik Blomen, and Eric Masanet. 2010. *Energy Efficiency Improvement and Cost Saving Opportunities for the U.S. Iron and Steel Industry: An ENERGY STAR Guide for Energy and Plant Managers.* Washington, DC: U.S. Department of Energy.	x	x		x
Hasanbeigi, Ali, Marlene Arens, and Lynn Price. 2013. Emerging Energy-Efficiency and Carbon Dioxide Emissions-Reduction Technologies for the Iron and Steel Industry. Washington, DC: U.S. Department of Energy.	x	x		x
U.S. Department of Energy (DOE). 2022. *Industrial Decarbonization Roadmap*. Washington, DC: DOE.	x			x
U.S. Department of Energy (DOE). 2015. *Bandwidth Study on Energy Use and Potential Energy Saving Opportunities in U.S. Pulp and Paper Manufacturing*. Washington, DC: DOE.	x			x
U.S. Department of Energy (DOE). 2024. "Industrial Assessment Center (IAC) Database." Washington, DC: DOE.		x		
U.S. Department of Energy (DOE). 2023. *Annual Energy Outlook 2023: Industrial Demand Module Assumptions.* Washington, DC: DOE.	x	x	x	x
Priority 4				
Thirumaran, Kiran, Sachin U. Nimbalkar, Arvind Thekdi, and Joe Cresko. 2019. *Energy Implications of Electrotechnologies in Industrial Process Heating Systems.* ACEEE Summer Study on Energy Efficiency in Industry.	x			x
Schoeneberger, Carrie, Jingyi Zhang, Colin McMillan, Jennifer B. Dunn, and Eric Masanet. 2022. *Electrification Potential of U.S. Industrial Boilers and Assessment of the GHG Emissions Impact*. Golden, CO: National Renewable Energy Laboratory (NREL).	x	x		x
DNV. 2021. "Industrial Agricultural Market Saturation Study for the California Public Utilities Commission (CPUC)."			x	
National Renewable Energy Laboratory (NREL). 2020. *System Advisory Model—Concentrated Solar Thermal Power for Industrial Process Heat. Golden, CO: NREL.*	x	x	x	
Illinois Technical Reference Manual (IL TRM). 2022. "Illinois Technical Reference Manual Version 11."	x	x	x	
Northwest Power and Conservation Council (NWPCC). 2023. "Regional Technical Forum (RTF) Unit Energy Savings Workbooks."	x	x		x

The study team uses the term "measure" to refer to activities and technology investments undertaken to save energy and/or reduce carbon emissions, regardless of the decarbonization category. The team defined and parameterized measures relative to a defined baseline equipment type. Each measure and its baseline equipment together make up a measure pair. Table A-4 summarizes the number of measure pairs in the measure list by MECS end-use category and by decarbonization category. The list is a compilation of measure pairs from the DNV measure library supplemented with additional measures identified in the "Stock Study", by the industrial sector subject matter experts, or as gaps in the Phase One Potential Study. The table identifies the set of measure pairs that the study team included in this study. The team considered but dropped additional measures during the modelling process when the team could not find supporting data (these are not included in Table A-4).

Table A-4. Summary of Measures by Manufacturing End Use Consumption Survey End Use and Decarbonization Category

MECS End Use	CCUS	Electrification	Energy Efficiency	Low-carbon Fuels	Total by End Use
Process Heating	0	120	43	85	248
Conventional Boiler Use	0	2	34	10	46
Facility HVAC	0	5	34	4	43
Machine Drive	0	0	37	0	37
Process Cooling and Refrigeration	0	0	13	0	13
All[a]	9	0	3	0	12
N/A (Measure relates to nonfuel energy use, feedstocks)	0	0	0	11	11
Facility Lighting	0	0	7	0	7
On-site Transportation	0	4	1	0	5
Electro-Chemical Processes	0	0	3	0	3
Other Process Use	0	0	2	0	2
Other Facility Support	0	0	0	0	0
Total by Resource	0	131	177	110	427

[a] Measure is applied to all end uses (e.g., Strategic Energy Management, Pre-Combustion Carbon Capture for Storage).

The study team defined "baseline equipment" in broad categories. For example, the Drying, Process Heating base measure represents a wide range of equipment for drying food or materials. Any of these technologies has the same function and the same types of measures apply. The use of broad categories is necessary because, in most cases, insufficient data is available to support a more granular analysis in the industrial sector.

The team prioritized a high degree of granularity for end uses and equipment that make up a larger share of industrial energy use, while end uses contributing less received more general treatment. For example, due to the importance of process energy in the Non-Metallic Minerals subsector, the study team modelled specific measures such as the addition of a pregrinding system to a ball mill for materials processing and indirect kiln firing for gas sinter kilns (high granularity). In contrast, lighting energy use represented only a small share of industrial use; the team included Lighting Controls as a single measure category without distinguishing among types of controls.

A.4 Adjustments to Old Measure Cost Data

The study team used trends in Industrial Assessment Centers (IAC) database total cost data to adjust the measure cost-per-savings information to reflect NYS costs in 2023. The team first adjusted the IAC database costs for inflation to represent 2024 dollars. The team converted all savings numbers to MMBtu and dropped the top 10% of costs-per-savings data to remove outliers. The team also dropped measure categories not needed for this analysis and those with only one data point. The team then ran a linear model predicting cost-per-savings as a function of state, measure type, year, and the interaction of measure type and year. This allows different states and measure types to fluctuate in cost over the years to best reflect market realities. It includes an overall linear time trend and a separate linear time trend for each measure type.

For most measures, the team used the model's prediction for New York State in 2024. However, in certain cases, the team used this model to adjust cost data from other sources.

Notably, cost trends included increased efficiency in measure installation, which reduced costs, and increasing difficulty in achieving savings, which increased costs. Together, these trends yielded flat cost-per-savings over time.

A.5 Economic Data Sources

NYSERDA provided data or guidance for most of the categories of economic data required to satisfy regulatory requirements. The study team supplemented this with data from the following sources:

- Inflation: Federal Reserve Bank short- and long-term inflation forecasts, Consumer Price Index
- Avoided cost of energy (electricity): NYISO's locational-based marginal price (LBMP) of electricity (in dollars per kilowatt-hour [$/kWh]) and hourly impact shape
- Avoided cost of generation capacity: NYISO Installed Capacity Model

- Avoided cost of carbon (electricity and natural gas): New York State Department of Environmental Conservation (DEC 2025)
- Regional Greenhouse Gas Initiative (RGGI) price adders: NYISO System and Resource Outlook Appendix E Data (NYISO 2024)

Table A-5 summarizes economic inputs by zone, forecast year, and hour of year.

Table A-5. Economic Input Variation by Region, Forecast Year, and Hour of Year

Metric or Cost Component	Zone	Tier	Year of Forecast	Hour of Year
Avoided cost of GHG			x	
Electricity avoided costs				
Energy (kWh)	x		x	
Generation capacity (kW)	x		x	
Transmission (kW)	x		x	
Distribution (kW)	x			
Natural gas avoided costs	x		x	
Electricity rates	x	x	x	
Natural gas rates		x	x	
Other fossil fuel prices			x	
RGGI price adder			x	
Electricity CO_2 emissions factors	x[a]		x	x

[a] Electricity CO_2 emissions factors vary between upstate and downstate only, not specific zones.

A.6 Emissions Data Sources

The model can accommodate, but does not require, hourly CO_2 emissions factors. The study team aligned upstream and downstream carbon and other greenhouse gas (GHG) emissions factors methodologies with the Climate Leadership and Community Protection Act (Climate Act). The team pulled emissions factors for electricity from NYSERDA's projected emissions factor for New York State grid electricity (NYSERDA 2023).

A.7 Decarbonization Potential Model

The study team developed and used an Excel-based, macro-assisted model to estimate decarbonization potential. The model consists of seven workbooks. Five workbooks house the model inputs, organized into load shapes and building stock, measures, avoided costs, rates and prices, and emissions inputs. The sixth workbook integrates these inputs and calculates key intermediate values and benefit/cost test results. Macros support this integration process, especially for hourly data, such as load shapes, avoided costs, and rates, which would otherwise be cumbersome and slow to process using standard Excel formulas.

The seventh workbook contains program assumptions and adoption parameters, along with the template used to calculate achievable potential. The team also used macros in this workbook to cycle through measure/segment combinations, run them through the spreadsheet calculation engine, and save the outputs to a results file.

The modelling consists of five key steps:

- **Step 1: Perform Foundational Calculations**
    - Incorporate stock, baseline equipment, measure, load shape, and emissions data
    - Match and integrate the data to calculate the measure savings, customer costs, and avoided costs
    - Calculate customer and societal benefit-cost tests
    - Estimate the immediate technical potential carbon reduction for each measure without accounting for measure competition
- **Step 2: Estimate Technical Potential**
    - Estimate annual technical potential using step 1 results, considering stock turnover, measure competition, and market delivery capacity
- **Step 3: Estimate Economic Potential**
    - Estimate annual economic potential using step 1 results, accounting for the societal cost test (SCT) (independent), stock turnover, measure competition, and market delivery capacity
- **Step 4: Estimate Achievable Program and Naturally Occurring Potentials**
    - Gather and develop estimates of program costs (e.g., for administration and marketing) and historical program participation and savings
    - Estimate customer adoption of carbon reduction measures based on economic attractiveness, adoption barriers, and program intervention effects
    - Estimate achievable program and naturally occurring potentials, and calibrate these to recent program and market data
- **Step 5: Scenario Analyses and Resource Planning Inputs**
    - Develop parameters for alternative scenarios of interest
    - Recalculate potentials under alternate scenarios

The following discussion provides further detail on the study team's modelling approaches for technical, economic, and achievable decarbonization forecasts.

A.8 Estimate Technical Potential

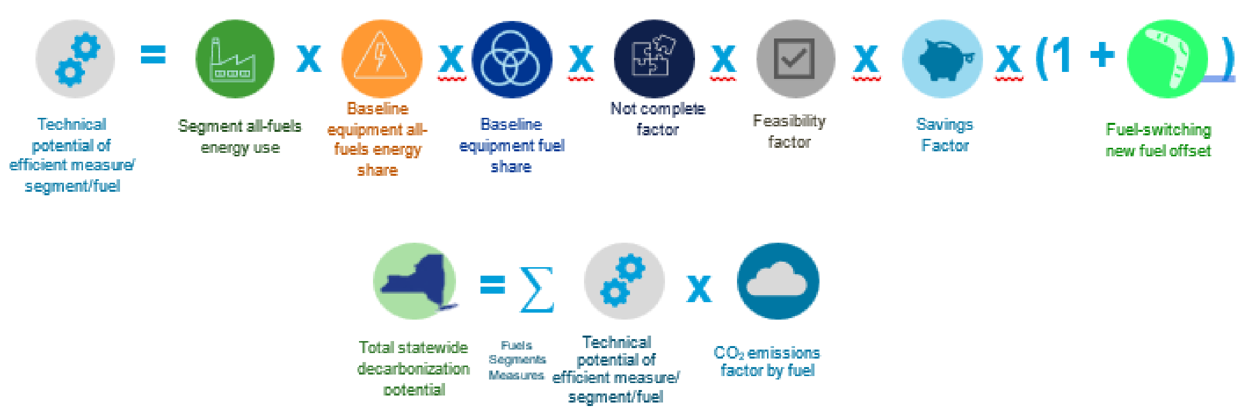
Immediate, no-competition technical potential refers to the amount of energy savings, peak demand reduction, or carbon reduction that results from the complete penetration of all measures analyzed in each application where the study team deemed them technically feasible from an engineering perspective. This calculation ignores stock turnover, cost-effectiveness, and the market's capacity to deliver measures. The team used this value as a high-level screen to eliminate measures that would not result in carbon savings.

The study team developed total technical potential from estimates of the technical potential of individual measures as they apply to discrete market segments (defined by subsector, expenditure tier, zone, and DAC proximity).

The core of the analysis involves estimating energy savings by fuel for each measure, or carbon savings directly for nonfuel measures. The model derives peak demand and carbon impacts by applying load shapes and carbon emissions profiles to these energy savings. To estimate high-level potential, the model aggregates measure-level results and assesses competing measures to maximize decarbonization.

Figure A-1 presents the core equation used to calculate the energy technical potential for each efficiency measure, by market segment and fuel. This simplified formula does not capture the element of time in technical potential or competition between measures; those elements are addressed in subsequent sections. The study team calculated energy savings potential for each fuel type, measure, and market segment. To estimate statewide decarbonization potential, the study team first estimated the carbon emissions associated with each calculated energy savings value, then summed the carbon savings across fuels, measures, and segments.

Figure A-1. Simplified Equations for Calculating Immediate, No-Competition Technical Potential



In Figure A-1:

- Segment all-fuels energy use is the normalizing unit for the study. This is the total energy consumption in million Btu for all fuels considered in the study for a particular market segment (subsector, tier, zone, DAC proximity). The study team abbreviated all-fuels energy use in MMBtu as all-fuels million British thermal units (AFMMBtu).
- Baseline equipment all-fuels energy share is the fraction of the base all-fuels energy use consumed by the baseline equipment; for example, the share of AFMMBtu used by electric water-cooled chillers.
- Baseline equipment fuel shares allocate AFMMBtu for the baseline equipment to specific fuels. For electricity impacts, the units are kWh per AFMMBtu. For fuels measured in MMBtu, the units are fuel MMBtu per AFMMBtu, equivalent to the share of AFMMBtu for that fuel (if the equipment uses only one fuel and is measured in Btu, the value is 1). For the water-cooled chiller example, the equipment fuel share for electricity would be the annual kWh per base all-fuels MMBtu for a standard efficiency electric water-cooled chiller, with shares for other fuels set to zero.
- Not-complete factor is the fraction of baseline equipment that has not yet been converted to the decarbonization measure; that is, 1 minus the measure saturation at the start of the study. In the chiller example, this is the share of electric water-cooled chillers that are not high efficiency. Depending on the baseline equipment's characteristics and specificity, the incomplete factor could be as high as 100%, such as for all electrification measures, for example.
- Feasibility factor is the fraction of baseline equipment for which the carbon reduction measure is technically feasible from an engineering perspective. Because the industrial analysis cannot characterize every industrial process with precision, the study team may find, for example, that infrared drying is not feasible for all drying applications in the food industry. This factor captures factors that limit measure installation, beyond what is captured in the other factors.
- Savings factor is the percent reduction in baseline end-use energy consumption or GHG emissions for the fuel impact being calculated, resulting from application of the measure. For energy efficiency measures, the savings factor is the percent reduction in baseline equipment energy consumption for the fuel savings being calculated, resulting from applying the efficient technology.
- Fuel-switching new fuel offset applies only to fuel-switching measures and is the increase in use of the switched-to fuel, in kilowatt-hours (kWh) or MMBtu, per MMBtu of the original fuel saved. For example, if the new equipment adds 260 kWh for each 1 MMBtu of natural gas saved compared to the old equipment, this value would be set to -260 (the model calculates savings as a positive value, so energy added is treated as negative savings). For non-fuel-switching measures, this value is set to zero.
- CO_2 emissions factor is the carbon dioxide emissions per unit of energy savings (MMBtu or kWh). If the model calculates electricity emissions hourly, this factor incorporates the savings load shape for the measure.

A.8.1 Technical Potential over Time

The equation in Figure A-1 represents the year calculation in Year 1. In subsequent years, an internal stock accounting replaces the first five elements of the formula, which represent base equipment energy use eligible for replacement by the measure. As equipment turns over or add-on measures are installed, the amount of base energy use available for replacement decreases.

The stock accounting algorithm handles capital turnover and stock decay for up to 26 years. In Year 1, the model begins with the fraction of base all-fuels energy use to which each measure will apply. The input to this calculation is the total base all-fuels energy use available for the measure from the technical potential analysis; that is, the segment all-fuels energy use multiplied by the not-complete and feasibility factors described previously. The study team refers to this as the eligible stock. The stock algorithm tracks the amount of base all-fuels consumption available for each efficiency measure in each year based on the total eligible stock and whether the application is new construction, retrofit, or replace-on-failure.

Retrofit measures are available for implementation by the entire eligible stock. Over time, adoptions and facility decay reduce the eligible stock. Replace-on-failure measures apply annually, with turnover approximated at a rate equal to the inverse of the service life. The Annual portion of the eligible market that does not accept the replace-on-failure measure does not have an opportunity again until the end of the service life of the baseline replacement adopted instead.

New construction applications are available for implementation in Year 1. The proportion of energy use that does not adopt the measure receives subsequent opportunities corresponding to whether the measure is a replacement or retrofit-type measure.

A.8.2 Measure Competition and Double Counting

The study team applied the following methodology from the New York Buildings Potential Study (NYSERDA 2023) for cases where competing measures were considered, to both avoid double-counting and allow some adoption of measures other than the one with the highest individual adoption rate:

1. Use the adoption model to determine the proportion p_j of base use adopting each competing measure j individually
2. Define p1 as the largest of the individual proportions pj

3. Calculate the "no-measures" proportion p0 as the complement of the maximum of the individual measures; that is, $p_0 = 1 - p_1$
4. Calculate the sum *S* of the individual competing measures' proportions, and the sum *D* including the no-measures proportion; that is, for a total of *m* competing measures

$$S = \sum_{i=1}^{m} p_i$$

$$D = \sum_{i=0}^{m} p_i = S + 1 - p_1$$

5. Calculate the adjusted proportion as

$$p'_j = p_j / D$$

The authors of the *Buildings Potential Study* did not address how they applied this approach when a mix of replace-on-burnout (ROB) and retrofit measures compete for the same base measure (NYSERDA 2023b). The study team believes the previous calculations must be done separately for ROB and retrofit measures to obtain sensible results in the model (since the ROB adoption percent is applied only to the share of base equipment that is turning over in a given year, while retrofits are not limited in this way). Essentially, ROB measures will compete only for the portion of the stock turning over naturally, while the retrofit measures compete without that restriction.

A.8.3 Technical Potential Addressing Measure Interaction

Where measures are not in competition, calculating technical potential is straightforward. One of the parameters of the model's adoption curves is maximum annual adoption. That parameter determines the annual share of the remaining technically eligible building stock that will adopt each year until no more installation opportunities exist.

Where different measures compete for the same opportunities, the model determines which of the competing measures has the highest savings potential (as assessed independently, without considering competing measures). When a single measure has the highest potential, the study team calculates its potential as described previously and assigns zero technical potential to the remaining competing measures. If multiple competing measures tie for the highest potential, each measure's potential is weighted by *1/n*, where *n* is the number of tied measures within the competition group.

A.9 Estimation of Economic Potential

Economic potential refers to the technical potential of those energy conservation measures that are cost-effective from a societal standpoint. For this study, cost-effectiveness is measured by the SCT. The test and its application in estimating economic potential are described in the following sections. Economic potential considers that many of the modelled measures cost more to purchase initially than their standard-efficiency counterparts. The incremental costs of each decarbonization measure are compared to the energy and carbon savings delivered by the measure over its lifetime to produce estimates of decarbonization impacts per unit of additional cost.

As noted in the body of the report, the study team produced two estimates of economic potential based on different forecasts for the SCT of GHG emissions from the New York State Department of Environmental Conservation (DEC). The DEC's forecasts differ in the discount rate applied to the future impacts of GHGs. The DEC identifies the forecasts by the discount rate it uses to calculate the higher and lower costs. The rates DEC used to develop its avoided costs of emissions are independent of the discount rate used for this study. The study team uses a 3% real discount rate for all scenarios, regardless of the forecast used for the avoided cost of GHG emissions.

The two estimated economic potential scenarios are:

1. Low SCT of carbon scenario: This scenario used the DEC's lowest estimate of the SCT of GHG emissions, which was developed using a 3% discount rate.
2. High SCT of carbon scenario: This scenario uses an alternative forecast for the SCT of GHG emissions that is higher than the forecast used in the low case (developed using a 2% discount rate, which the DEC characterizes as their central rate).

A.9.1 Use of the Societal Cost Test to Estimate Economic Potential

This section provides an overview of how the study assessed the cost-effectiveness of energy measures, explaining the methods used to determine which measures offer economic value from a societal perspective, focusing on the SCT.

To estimate economic potential, the study team developed a method to determine whether a measure or market intervention is economic. New York State uses the SCT for energy efficiency program filings, and the study team used the SCT as the primary cost-effectiveness test for this study (PSC 2016).

The SCT measures the net costs of a market intervention based on its total costs and benefits, including both the participants' and the program administrator's costs and benefits, as well as externalities (such as the cost of carbon, other environmental impacts, and public health impacts). Table A-6 summarizes the costs and benefits included in the test. The SCT uses a societal discount rate and applies to conservation, load management, and fuel substitution programs. For fuel substitution measures, the test compares the net effect of the impacts from the fuel not chosen versus the impacts from the fuel selected because of the switching measure. The study team views SCT test results for fuel substitution as a measure of the economic efficiency of a measure, considering the total energy supply system, GHG impacts, and nonenergy impacts.

Table A-6. Societal Cost Test Included Benefits and Costs

Benefits	Costs
Generation, transmission, and distribution avoided costs	Program costs paid by the administrator
Participants avoided equipment costs (fuel switching only)	Net participant measure costs[a]
Value of carbon and other GHG reduction	
Nonenergy impacts (net)	

[a] The increase in participant measure costs due to the market intervention, compared to the no-intervention case.

The study team defines generation, transmission, and distribution savings (hereafter, energy benefits) as the economic value of the energy and demand savings stimulated by the interventions being assessed. These benefits are typically measured as induced changes in energy consumption, valued using some mix of avoided costs. The study team values electricity benefits using three types of avoided electricity costs: avoided distribution costs, avoided transmission costs, and avoided electricity generation costs. The latter includes both capacity costs ($/kW) and energy costs ($/kWh generated).

Participant costs primarily consist of incremental measure costs. The study team defines "incremental measure costs" as the cost of obtaining the measure, relative to the baseline costs. In the case of an add-on device (say, an adjustable-speed drive), the incremental cost is simply the installed cost of the measure itself. In the case of equipment that is available in various levels of efficiency (e.g., a rooftop unit), the incremental cost is the excess of the cost of the high-efficiency unit over the cost of the base (reference) unit.

Administrative costs include the real resource costs of program administration, such as the costs of administrative personnel, program promotions, overhead, measurement and study, and shareholder incentives. In this context, the study team does not define administrative costs to include the costs of various incentives (e.g., customer rebates, salesperson incentives) that may be offered to encourage certain types of behavior. The team excludes these incentive costs because they are essentially transfer payments. That is, from a societal perspective, they involve offsetting costs (to the program administrator) and benefits (to the recipient).

In addition to the SCT, the study team calculated the participant benefit/cost ratio for each measure. This benefit/cost ratio evaluates costs and benefits from the facility's perspective, comparing lifecycle costs to lifecycle benefits. On the benefits side, the ratio includes bill impacts and any nonenergy impacts to the

facility (including O&M cost decreases). The team compares these benefits to measure costs net of any incentives. The model uses the participant benefit/cost ratio to drive its adoption algorithm because a measure with a high benefit/cost ratio is a more attractive investment than one with a low ratio.

The study team developed an estimate of economic potential by calculating the SCT of individual measures and applying the methodology described below.

The study team can define economic potential either inclusively or exclusively of the costs of programs designed to increase the adoption rate of energy efficiency, electrification, low-carbon fuels, and CCUS measures. For this study, the team defined economic potential to exclude program costs primarily because economic potential should be unrelated to programs that aim to encourage adoption. Thus, the study team defines economic potential as the portion of the technical potential that passes the economic screening test (described below), exclusive of program costs. Like technical potential, economic potential is a theoretical quantity that exceeds the amount of potential estimated to be achievable through current or more aggressive program activities.

The SCT focuses on resource savings, counting benefits as avoided supply costs and the value of carbon mitigated, and costs as measure costs and program costs (excluding incentives). The test ignores any impact on rates. The SCT also treats financial incentives and rebates as transfer payments; that is, the SCT is not affected by incentives. The somewhat simplified benefit and cost formulas for the SCT are presented in Equations 1 and 2.

Equation 1. Societal Cost Test Benefits Calculation

$$\text{Benefits} = \sum_{t=1}^{N} \frac{Avoided\ Costs\ of\ Supply_t + Avoided\ Cost\ of\ Carbon_t + Value\ of\ Non{-}energy\ benefits_t}{(1 + \mathrm{d})^{\mathrm{t-1}}}$$

Equation 2. Societal Cost Test Cost Calculation

$$\text{Costs} = \sum_{t=1}^{N} \frac{Program\ Cost_t + Participant\ Cost_t + Non - energy\ Costs_t}{(1 + \mathrm{d})^{\mathrm{t-1}}}$$

Where:

d = the nominal discount rate
p = the costing period
t = time (in years)
N = 26 years

The model uses a real discount rate because all calculations are performed using real dollars.

The study team calculated the avoided costs of supply by multiplying measured energy savings and peak demand impacts by per-unit avoided costs on an hourly (8,760) basis. The team allocated energy savings hourly and estimated peak impacts using load shape factors.

As noted, the measure-level SCT calculation used to estimate economic potential excludes program costs from Equation 2.

The study team modelled the measure interaction and competition in the same way as for technical potential (discussed earlier), except that only measures passing the SCT compete. Because different measures compete when calculating technical and economic potential, economic potential for a measure may exceed its technical potential. In aggregate, technical potential exceeds economic potential, but this may not hold for specific measures or categories.

A.10 Estimation of Achievable and Naturally Occurring Potentials

This section presents the method the study team used to estimate the fraction of the market that adopts each measure in the presence and absence of programs. The study team defines:

- "Achievable potential" as the savings potential under specific scenarios representing real-world factors that can affect customer adoption decisions.
- "Naturally occurring potential" as the amount of impact estimated to occur as a result of normal market forces, that is, in the absence of any utility or governmental intervention.

The study team considers the estimates of achievable potential to be the most important results of the modelling process. Estimating technical and economic potentials is a necessary step in the process and provides important information. However, the goal of the process is to better understand how much of the remaining potential can be captured, whether it would be cost-effective to increase program spending, and how program costs may change in response to measure adoption over time.

A.11 Adoption Method Overview

This study used a method of estimating measure adoption that applies equally to program and naturally occurring analyses. While some adoption modelling frameworks (e.g., the Bass Diffusion Model) explicitly model market penetration as a function of time, this adoption model predicts annual measure adoption among available, aware customers as a function of the customer's benefit/cost ratio, given specific market barriers. The absolute level of adoption, and ultimately market penetration, changes over time due to changes in each of the following four factors:

- **The availability of the adoption opportunity relative to the total base consumption a measure targets**.
  This depends on capital equipment turnover rates, the measure implementation type (retrofit or replace-on-failure), and changes in facility stock over time. The rate at which existing equipment reaches end-of-life limits the availability of a replace-on-failure, while the entire stock of baseline equipment is available for a retrofit measure. Availability decreases over time as measures saturate the market. As more facilities adopt a measure, fewer remain yet to adopt. All else equal, this leads to decreased annual adoption over time as an increasingly smaller number of facilities remain that have not yet adopted the measure.
- **Customer awareness of the measure.**
  Awareness increases over time through both naturally occurring channels and program interventions represented through the marketing budget. All else equal, higher awareness results in higher adoption over time.
- **The cost-effectiveness of the measure to potential adopters:**
  - Measure costs for some measures may fall over time, resulting in a higher benefit/cost ratio and increased annual adoption (all else equal).
  - Some measures that are not cost-effective early in the forecast may become cost-effective in later years. This may result from decreasing measure costs; for fuel-switching measures, relative fuel costs may also be a factor. For low-carbon fuels, both fuel costs and availability influence adoption.
  - Program interventions may also change over time, potentially increasing or decreasing the customer's benefit/cost ratio and adoption rates.
- **Market barriers associated with the measure.**
  Market barriers may decrease over time, resulting in higher annual adoption.

Modelling adoption through the channels of stock turnover, awareness, cost-effectiveness, and market barriers allows the study team to explicitly model a variety of market interventions. The market penetration forecast results from the interplay between these factors as they change over time.

The study team used the same stock accounting for the achievable analysis as for technical potential (described earlier).

In the modelling framework, customers cannot adopt a measure merely because stock is available for conversion. Before making the adoption choice, they must be aware and informed about the measure. In the second stage of the process, the model calculates the portion of the available market that is informed.

An initial parameter sets the initial level of awareness for each measure (individually or categorically). The model simulates incremental awareness as a function of the amount of money spent on awareness/information building and the cost to reach each customer.

The model also controls for information retention. An information decay parameter controls for the percentage of customers who will retain program information from one year to the next. Information retention depends on the target audience and the effectiveness of the marketing techniques used.

The portion of the total market that is available and aware can now face the choice of whether to adopt a particular measure. Only customers for whom a measure is available for implementation (stage 1) and who have been informed about the program/measure (stage 2) can make the implementation decision.

In the third stage of the penetration process, the model calculates the fraction of the market that adopts each measure annually based on the participant test. The participant test is a benefit/cost ratio that is generally calculated as follows:

Equation 3. Participant Cost Test Benefit Calculation

$$\text{Benefits} = \sum_{t=1}^{N} \frac{Customer\ Bill\ Savings_t + Customer\ Non{-}energy\ Benefits_t}{(1 + \mathrm{d})^{\mathrm{t-1}}}$$

Equation 4. Participant Cost Test Cost Calculation

$$\text{Costs} = \sum_{t=1}^{N} \frac{Incremental\ Participant\ Measure\ and\ O\&M\ Costs_t - Incentives_t}{(1 + d)^{t-1}}$$

Where:

d = the discount rate
t = time (in years)
N = measure lifetime

The study team calculated bill reductions by multiplying measure energy savings and customer peak demand impacts by retail energy and demand rates.

The model uses measure implementation curves to estimate the percentage of the informed market that adopts each measure based on the participant's benefit/cost ratio. The model provides enough flexibility so that each measure in each market segment can have a separate implementation rate curve. The functional form used for the implementation curves is:

Equation 5. Implementation Curve Calculation

$$y = \frac{a}{1 + (4/x) \times (1 + (bx)^{-c})}$$

where:

y = the fraction of the market that installs a measure in a given year from the pool of available, aware customers
x = the customer's benefit/cost ratio for the measure
a = the maximum annual adoption rate for the technology
b = the inflection point of the curve (generally 1 over the benefit/cost ratio that gives one-half the maximum value)
c = the parameter that determines the general shape (slope) of the curve

Figure A-2 shows examples of the curves used in the model. The study team uses different curves to reflect different levels of market barriers for different efficiency measures. The chart shows a range of benefit/cost ratios that extends beyond the level where program intervention is typically used to increase measure adoption (the market rapidly adopts measures with a benefit/cost ratio of 30 without intervention). The study team included the extended range to show how the *a* parameter (maximum annual adoption) influences the curves: annual adoption asymptotically approaches the specified maximum as the benefit/cost ratio increases.

Table A-7 lists classic market barriers. These barriers necessitate program interventions to increase the adoption of conservation measures.

Figure A-2. Primary Measure Implementation Curves Used in the Adoption Model

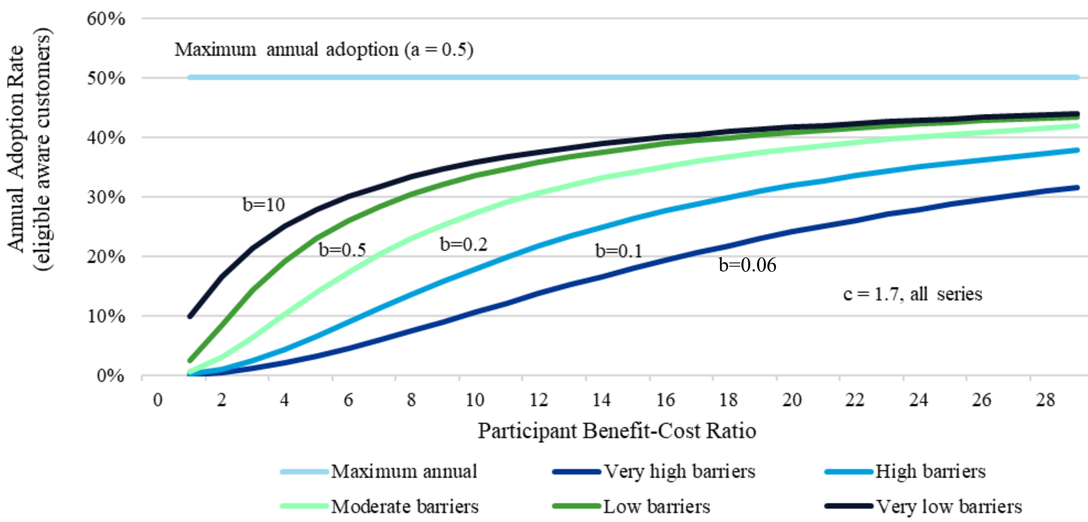


Table A-7. Description of Market Barriers

Source: Eto, Prahl, and Schlegel (1996).

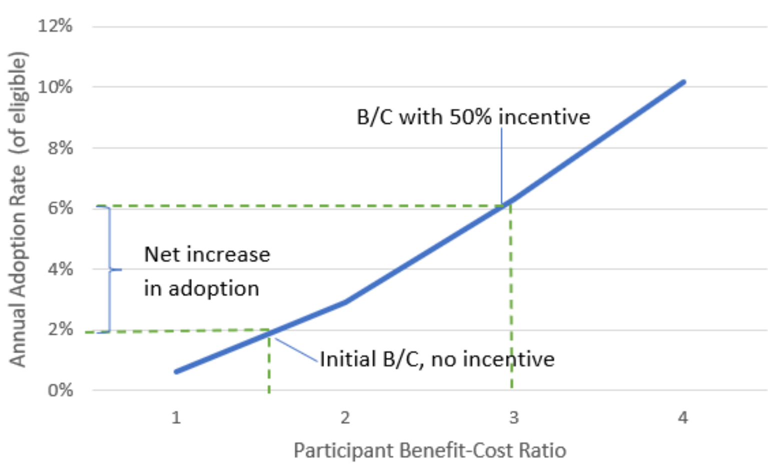
Barrier	Description
Information or Search Costs	The costs of identifying energy-efficient products or services, or of learning about energy-efficient practices, include the value of time spent researching or locating a product or service, or hiring someone else to do so.
Performance Uncertainties	The difficulties consumers face in evaluating claims about future benefits. Closely related to high search costs because acquiring the information needed to evaluate future performance is rarely costless.
Asymmetric Information and Opportunism	The tendency of sellers of energy-efficient products or services to have more and better information about consumers than consumers themselves, which, combined with potential incentives to mislead, can lead to suboptimal purchasing behavior.
Hassle or Transaction Costs	The indirect costs of acquiring energy efficiency include the time, materials, and labor involved in obtaining or contracting for an energy-efficient product or service. (Distinct from search costs because it refers to what happens after locating a product.)
Hidden Costs	Unexpected costs associated with reliance on or operation of energy-efficient products or services, for example, extra operating and maintenance (O&M) costs.
Access to Financing	The difficulties associated with the lending industry's historic inability to account for the unique features of loans for energy-savings products (e.g., future reductions in utility bills that improve loan repayment ability.
Bounded Rationality	The behavior of individuals during decision-making that either seems or is inconsistent with their own goals.
Organization Practices or Customs	Organizational behaviors or systems of practice that discourage or inhibit cost-effective energy efficiency decisions (e.g., procurement rules that hinder decisions based on economic merit).

Barrier	Description
Misplaced or Split Incentives	Cases where the incentives of an agent responsible for purchasing energy efficiency do not align with those who would benefit from the purchase.
Product or Service Unavailability	The failure of manufacturers, distributors, or vendors to make a product or service available in a given area or market. May result from collusion, bounded rationality, or supply constraints.
Externalities	Costs associated with transactions that are not reflected in the price paid during the transaction.
Nonexternality Pricing	Factors other than externalities that cause prices to deviate from marginal cost. For example, utility prices may be set using ratemaking practices based on average (rather than marginal) costs.
Inseparability of Product Features	Consumers struggle when desirable energy efficiency features are bundled with undesired features, driving the total product cost beyond what they are willing to pay.
Irreversibility	The difficulty of reversing a purchase decision arises when new information becomes available, potentially deterring the initial purchase (e.g., if energy prices decline, the resale of insulation blown into a wall becomes challenging).

The model estimates adoption under both naturally occurring and program intervention scenarios, with only two differences between the two cases. First, awareness differs due to program marketing and outreach activities, which increase awareness compared to the naturally occurring case. In the naturally occurring case, initial awareness and awareness growth are tied to the measure's cost-effectiveness.

Second, in any program case where incentives are provided, the model adjusts participant benefit/cost ratios to reflect those incentives. For example, if the program pays 50% of the incremental measure cost, the participant's benefit/cost ratio doubles because the cost has been halved. The resulting impact on estimated adoption depends on where the pre- and post-incentive benefit/cost ratios fall on the curve. Figure A-3 illustrates this effect.

Figure A-3. Effect of Incentives on Adoption Level as Characterized in Implementation Curves



A.11.1 Adoption over Time

Figures A-4 through A-9 provide graphical examples of how the various elements of the adoption modelling process interact. The numbers are for illustration only and do not represent a specific subsector. The even-numbered figures show the available stock, percent aware, and the total available aware stock.

- Available stock declines over time as customers adopt the measure and therefore are no longer available to install the measure.
- Percent awareness grows over time due to a combination of naturally occurring increases in awareness and the effects of program marketing.
- The total available aware stock combines these two factors. In this example, increases in awareness do not offset the decreases in available stock, so this curve flattens over time and the available aware stock starts to decline in Years 19 and 20 of the forecast.

Figure A-4. Adoption Modelling Example: Available Stock

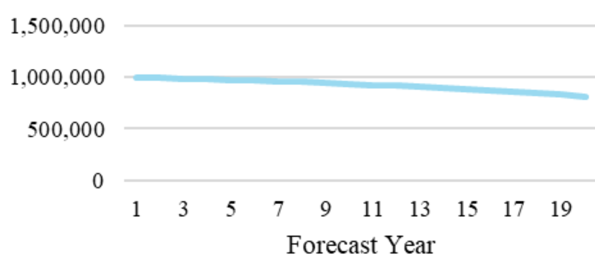


Figure A-5. Adoption Modelling Example: Benefit/Cost Ratio

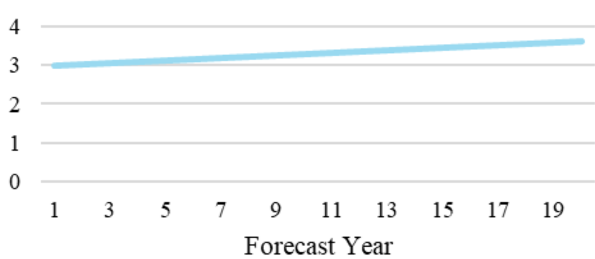


Figure A-6. Adoption Modelling Example: Percent Aware

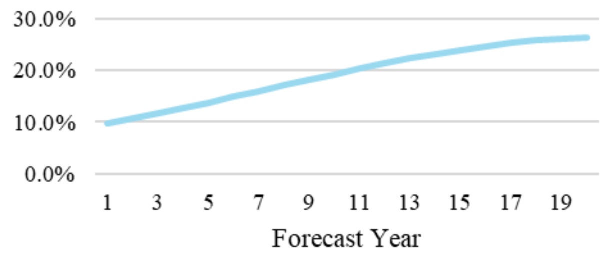


Figure A-7. Adoption Modelling Example: Annual Implementation Rate

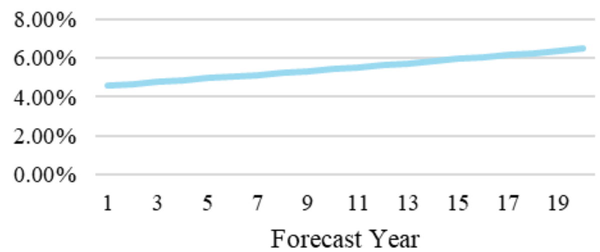


Figure A-8. Adoption Modelling Example: Total Available Stock Aware

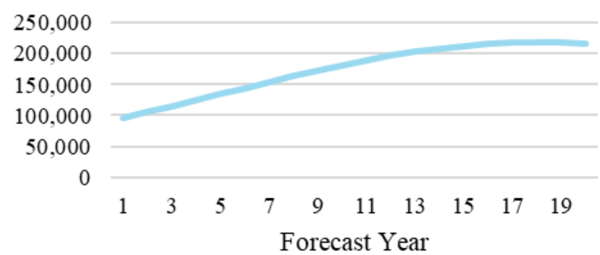
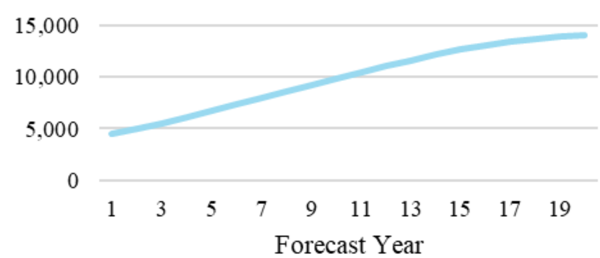


Figure A-9. Adoption Modelling Example: New Adoptions



The odd-numbered figures show the customer benefit/cost ratio, the annual implementation rate, and the overall new adoptions.

- The study team assumed that the benefit/cost ratio increases over the forecast period due to declining measure costs.
- The annual implementation rate increases, driven by improving measure economics.
- Applying the annual implementation rate to the total available stock awareness generates a forecast of new adoptions with a modest S shape. Initially, adoptions increase at a steady rate, but the curve hits an inflection point in Year 9 in the example. Adoption continues to increase, but at a decreasing rate. With a longer forecast horizon (or with higher rates of adoption), annual adoption would eventually start to decline.

A.11.2 Scenarios

Once the model includes the base modelling assumptions, the study team reran the model to estimate potential under different scenarios. Section 1.2 describes the scenarios.

A.12 Disadvantaged Communities

The study team included disadvantaged communities (DAC), in or out, as one element of the facility segmentation. The team analyzes facilities located within 3 miles of a DAC separately from those located outside that radius, allowing easy reporting of overall savings or decarbonization potential that impacts one or more DACs. This approach focuses on facilities and does not capture the additive impacts on a DAC located near multiple industrial facilities.

Assessing the savings potential of a particular DAC requires a geographic analysis. Fortunately, the “Stock Study” included a GIS analysis that assessed which facilities are within 3 miles of a DAC, their aggregate emissions affecting the DAC, and the emissions share for each facility. This analysis does not aim for accuracy at the individual facility level but is meaningful in aggregate. This study used the geographic analysis from the “Stock Study” to identify potential aggregate reductions to emissions affecting a DAC.

To use this rich analysis for the potential study, the study team mapped the segment-level (combined subsector, expenditure tier, NYISO zone, and DAC proximity) results back to the facility level. The “Stock Study” and this study’s baseline analysis broke out base energy use by segment based on facility-level analysis. Based on that mapping, the study team allocated savings potential for each segment to facilities within that segment in proportion to their base energy consumption. Within a tier, zone, and subsector, facilities in DAC areas receive the same percent savings as facilities outside these areas.

Appendix B. Separate Technical and Economic Potential by Decarbonization Category

To assess the effect of competition between measures on the relative savings by category, the study team estimated potential for each category in isolation—that is, assuming measures in the other decarbonization categories were not available.

Table B-1 and Figure B-1 present the technical emissions savings potential for these stand-alone runs compared to the technical potential developed with all measures in competition. Table B-2 shows the corresponding economic results with the low and high carbon dioxide (CO_2) values, and Figure B-2 presents the results with the high CO_2 values. Table B-3 and Table B-4 present the same information for stand-alone energy savings potential.

Table B-1. Comparison of Stand-alone Cumulative Emissions Savings Technical Potential by Category to Technical Potential with Competition

Values in $MtCO_2e$.

Year	Technical Competition Results				Technical Stand-alone Results			
	Energy Efficiency	Electrification	Low-carbon Fuels	CCUS	Energy Efficiency	Electrification	Low-carbon Fuels	CCUS
2025	765,274	249,739	43,998	0	752,386	273,443	62,382	0
2026	1,250,684	335,101	144,127	7,395	1,230,711	535,178	205,716	14,901
2027	1,637,403	411,958	290,469	21,247	1,613,805	780,177	418,864	42,814
2028	1,857,490	488,059	479,323	42,053	1,863,810	1,016,671	696,798	84,535
2029	1,936,372	564,762	704,711	70,292	1,952,796	1,255,380	1,030,087	141,304
2030	1,813,162	651,168	959,400	107,330	1,844,548	1,514,893	1,407,543	215,762
2031	1,816,328	739,132	1,233,880	150,599	1,867,108	1,759,028	1,815,293	302,745
2032	1,737,205	855,025	1,511,604	202,258	1,810,695	2,030,202	2,239,598	406,610
2033	1,644,231	978,656	1,784,631	261,939	1,743,517	2,316,756	2,667,409	526,602
2034	1,524,619	1,126,902	2,047,450	330,105	1,651,396	2,665,881	3,086,957	663,665
2035	1,387,662	1,288,296	2,293,026	425,661	1,542,165	3,046,145	3,486,392	855,861
2036	1,253,208	1,434,898	2,518,693	530,817	1,434,951	3,410,502	3,856,986	1,067,413
2037	1,140,127	1,561,738	2,724,215	645,039	1,348,896	3,735,293	4,193,115	1,297,249
2038	1,054,820	1,836,782	2,814,913	768,598	1,289,184	4,008,070	4,491,265	1,546,012
2039	992,995	2,061,394	2,893,931	901,129	1,251,368	4,232,194	4,749,220	1,812,988
2040	951,980	2,235,562	2,962,730	1,042,596	1,236,433	4,408,558	4,967,511	2,097,928
2041	923,259	2,368,521	3,022,646	1,193,506	1,234,443	4,551,193	5,148,319	2,401,897

Table B-1. (continued)

Year	Technical Competition Results				Technical Stand-alone Results			
	Energy Efficiency	Electrification	Low-carbon Fuels	CCUS	Energy Efficiency	Electrification	Low-carbon Fuels	CCUS
2042	904,672	2,467,026	3,074,692	1,353,644	1,243,094	4,666,002	5,294,693	2,724,444
2043	893,892	2,537,468	3,119,662	1,522,590	1,260,525	4,758,164	5,410,360	3,064,699
2044	887,242	2,587,736	3,158,573	1,701,219	1,283,083	4,834,938	5,500,138	3,424,423
2045	883,258	2,622,938	3,190,580	1,880,994	1,307,990	4,900,640	5,565,250	3,786,476
2046	880,993	2,648,204	3,217,173	2,062,038	1,334,183	4,958,842	5,612,624	4,151,103
2047	880,126	2,666,289	3,239,367	2,243,874	1,361,694	5,010,994	5,647,118	4,517,317
2048	879,376	2,679,727	3,258,025	2,426,771	1,389,628	5,059,182	5,672,315	4,885,673
2049	878,949	2,689,909	3,273,788	2,610,643	1,417,715	5,104,438	5,690,781	5,255,998
2050	879,035	2,697,529	3,287,174	2,795,519	1,446,483	5,146,766	5,704,364	5,628,337

Figure B-1. Stand-alone Cumulative Emissions Reduction Technical Potential by Category

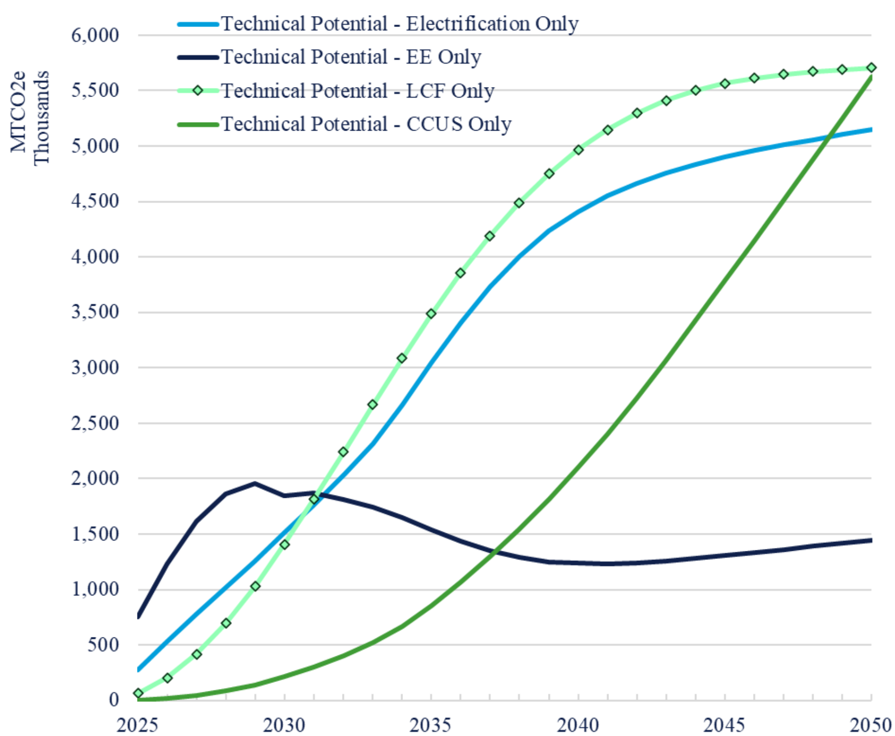


Table B-2. Comparison of Stand-alone Cumulative Emissions Savings High Carbon Dioxide Value Economic Potential by Category to High Carbon Dioxide Value Economic Potential with Competition

Values in $MtCO_2e$.

Year	High CO_2 Value Economic Competition Results				High CO_2 Value Economic Stand-alone Results			
	Energy Efficiency	Electrification	Low-carbon Fuels	CCUS	Energy Efficiency	Electrification	Low-carbon Fuels	CCUS
2025	499,716	244,261	2	0	502,870	269,017	3	0
2026	829,777	329,314	6,139	4,183	830,917	526,349	7,696	8,534
2027	1,104,762	411,434	17,200	12,033	1,102,541	766,280	21,630	24,549
2028	1,277,409	499,745	32,713	23,893	1,290,946	995,311	41,253	48,595
2029	1,359,630	592,808	51,961	40,065	1,374,708	1,221,869	65,661	81,486
2030	1,310,362	697,969	74,125	61,509	1,327,360	1,459,322	93,789	125,088
2031	1,343,810	788,382	98,265	86,427	1,364,313	1,657,609	124,399	175,762
2032	1,322,996	882,406	123,467	116,344	1,346,783	1,852,043	156,265	236,605
2033	1,292,139	974,445	148,875	150,982	1,319,897	2,023,563	188,229	307,049
2034	1,241,859	1,063,874	173,816	191,056	1,274,075	2,167,729	219,337	388,542
2035	1,177,784	1,168,300	197,638	285,394	1,215,569	2,317,270	248,686	578,344
2036	1,113,115	1,272,793	219,791	389,476	1,155,623	2,456,459	275,618	787,777
2037	1,061,205	1,372,188	239,941	502,851	1,108,164	2,579,932	299,693	1,015,940
2038	1,027,025	1,477,776	253,275	625,788	1,077,570	2,689,453	320,873	1,263,461
2039	1,008,012	1,580,149	266,559	757,877	1,061,197	2,786,718	341,578	1,529,536
2040	1,003,198	1,679,010	278,108	899,059	1,060,328	2,872,466	358,867	1,813,899
2041	1,006,471	1,775,488	288,023	1,049,775	1,068,097	2,950,139	372,973	2,117,471
2042	1,016,467	1,869,744	296,426	1,209,786	1,083,077	3,021,146	384,207	2,439,759
2043	1,032,291	1,961,884	303,476	1,378,660	1,104,055	3,086,619	392,938	2,779,865
2044	1,053,679	2,052,772	309,356	1,557,248	1,131,584	3,148,341	399,575	3,139,508
2045	1,076,474	2,141,029	313,982	1,736,998	1,160,070	3,206,420	404,253	3,501,510
2046	1,099,500	2,227,087	317,662	1,918,026	1,194,271	3,261,802	407,553	3,866,102
2047	1,126,213	2,310,968	320,616	2,099,852	1,227,347	3,314,836	409,881	4,232,294
2048	1,151,630	2,392,903	323,008	2,282,740	1,259,269	3,365,990	411,522	4,600,633
2049	1,176,329	2,472,973	324,960	2,466,606	1,290,267	3,415,522	412,680	4,970,944
2050	1,200,705	2,551,183	326,560	2,651,478	1,321,044	3,463,465	413,496	5,343,273

Figure B-2. Stand-alone Cumulative Emissions Reduction Economic High Carbon Dioxide Value Potential by Category

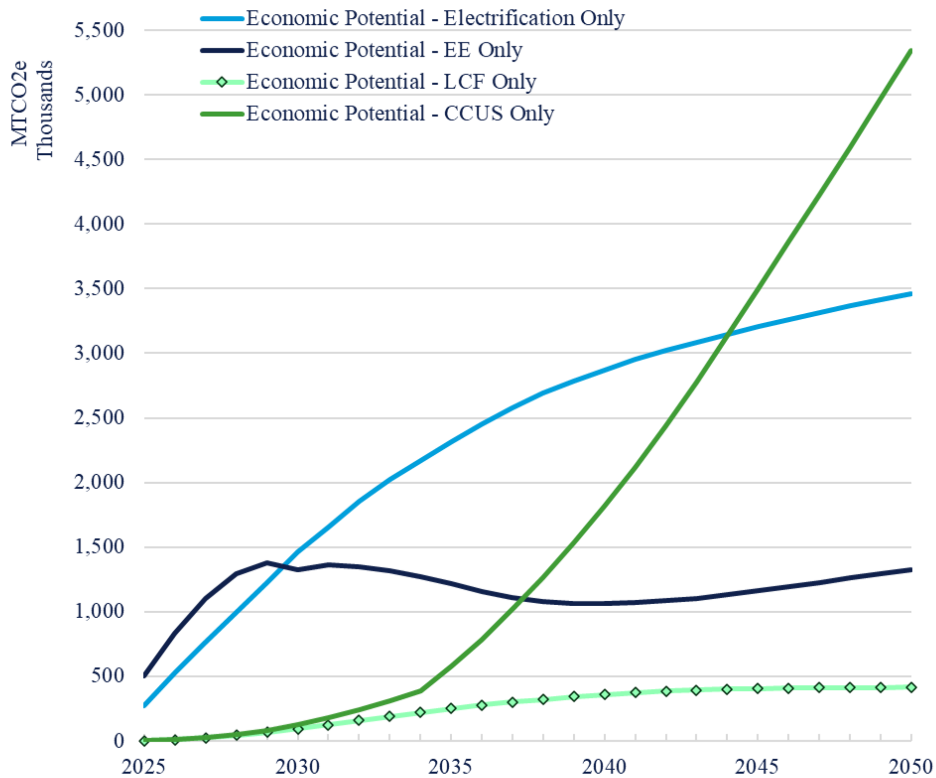


Table B-3. Comparison of Stand-alone Cumulative Energy Savings Technical Potential by Category to Technical Potential with Competition

Values in MMBtu.

Year	Technical Competition Results				Technical Stand-alone Results			
	Energy Efficiency	Electrification	Low-carbon Fuels	CCUS	Energy Efficiency	Electrification	Low-carbon Fuels	CCUS
2025	6,518,990	2,772,592	0	0	6,525,567	3,009,793	0	0
2026	11,614,998	3,662,111	0	-12,010	11,629,234	5,760,279	0	-24,212
2027	15,680,579	4,505,141	0	-34,184	15,709,484	8,346,646	0	-68,921
2028	18,976,270	5,282,521	0	-66,566	19,032,595	10,728,017	0	-134,223
2029	21,665,484	5,992,820	0	-108,998	21,770,399	12,906,544	0	-219,805
2030	23,889,595	6,569,954	0	-161,362	24,068,851	14,786,503	0	-325,431
2031	25,742,343	6,755,645	0	-223,499	26,029,803	16,015,319	0	-450,792
2032	27,301,730	6,848,363	0	-295,393	27,735,944	16,999,622	0	-595,860
2033	28,629,063	6,941,701	0	-377,154	29,249,329	17,525,641	0	-760,865
2034	29,768,143	6,915,600	0	-468,790	30,613,702	17,360,180	0	-945,827
2035	30,749,598	7,073,624	0	-561,061	31,859,024	17,486,635	0	-1,132,095
2036	31,600,991	7,228,900	0	-661,918	33,010,883	17,614,846	0	-1,335,725
2037	32,346,571	7,353,751	0	-771,298	34,087,509	17,733,732	0	-1,556,597
2038	33,008,677	6,995,171	0	-890,039	35,111,086	17,880,127	0	-1,796,397
2039	33,601,366	6,727,459	0	-1,017,839	36,092,516	18,056,404	0	-2,054,512
2040	34,137,978	6,533,651	0	-1,154,822	37,043,109	18,260,773	0	-2,331,199
2041	34,631,641	6,398,043	0	-1,301,195	37,971,165	18,490,260	0	-2,626,869
2042	35,089,794	6,307,435	0	-1,456,768	38,881,485	18,740,260	0	-2,941,134
2043	35,517,931	6,250,972	0	-1,621,201	39,777,059	19,005,717	0	-3,273,291
2044	35,922,333	6,219,427	0	-1,795,247	40,664,421	19,282,878	0	-3,624,870
2045	36,308,946	6,206,839	0	-1,970,358	41,547,181	19,563,899	0	-3,978,610
2046	36,681,824	6,206,433	0	-2,146,596	42,428,101	19,845,272	0	-4,334,632
2047	37,041,682	6,213,708	0	-2,323,652	43,249,960	20,123,912	0	-4,692,309
2048	37,391,158	6,225,623	0	-2,501,739	44,023,502	20,397,799	0	-5,052,072
2049	37,733,308	6,240,205	0	-2,680,725	44,796,174	20,665,633	0	-5,413,651
2050	38,069,127	6,256,155	0	-2,860,656	45,568,307	20,926,400	0	-5,777,139

Table B-4. Comparison of Stand-alone Cumulative Energy Savings High Carbon Dioxide Value Economic Potential by Category to High CO_2 Value Economic Potential with Competition

Values in MMBtu.

Year	High CO_2 Value Economic Competition Results				High CO_2 Value Economic Stand-alone Results			
	Energy Efficiency	Electrification	Low-carbon Fuels	CCUS	Energy Efficiency	Electrification	Low carbon FUELS	CCUS
2025	4,265,748	2,711,153	0	0	4,367,547	2,961,536	0	0
2026	7,693,563	3,570,802	0	-8,430	7,836,473	5,665,741	0	-17,133
2027	10,542,423	4,425,454	0	-23,967	10,692,763	8,184,593	0	-48,716
2028	12,931,279	5,277,140	0	-46,627	13,091,346	10,497,045	0	-94,785
2029	14,944,882	6,102,155	0	-76,247	15,122,241	12,605,487	0	-155,020
2030	16,674,072	6,895,021	0	-112,733	16,871,664	14,490,195	0	-229,234
2031	18,180,267	7,652,490	0	-155,957	18,397,036	16,146,204	0	-317,175
2032	19,514,666	8,373,891	0	-205,910	19,749,103	17,617,535	0	-418,831
2033	20,713,892	9,058,285	0	-262,643	20,967,098	18,833,469	0	-534,312
2034	21,805,828	9,681,489	0	-326,145	22,079,172	19,723,765	0	-663,601
2035	22,813,260	10,406,199	0	-418,416	23,145,859	20,625,045	0	-849,869
2036	23,751,857	11,118,398	0	-519,272	24,129,951	21,439,387	0	-1,053,500
2037	24,636,242	11,791,842	0	-628,652	25,046,730	22,163,104	0	-1,274,372
2038	25,480,402	12,448,343	0	-747,393	25,925,139	22,826,680	0	-1,514,172
2039	26,288,920	13,111,643	0	-875,193	26,777,968	23,438,393	0	-1,772,287
2040	27,108,750	13,780,724	0	-1,012,176	27,598,698	24,007,051	0	-2,048,974
2041	27,904,273	14,455,148	0	-1,158,549	28,396,819	24,541,127	0	-2,344,643
2042	28,680,209	15,133,175	0	-1,314,123	29,192,628	25,046,864	0	-2,658,908
2043	29,446,633	15,812,584	0	-1,478,556	29,971,041	25,529,025	0	-2,991,066
2044	30,231,539	16,494,166	0	-1,652,602	30,778,540	25,993,742	0	-3,342,644
2045	31,007,752	17,163,410	0	-1,827,712	31,582,118	26,436,123	0	-3,696,385
2046	31,784,540	17,820,659	0	-2,003,950	32,441,546	26,860,925	0	-4,052,407
2047	32,537,517	18,464,942	0	-2,181,006	33,225,119	27,270,537	0	-4,410,083
2048	33,235,869	19,096,023	0	-2,359,093	33,970,768	27,666,492	0	-4,769,847
2049	33,928,660	19,713,694	0	-2,538,079	34,695,580	28,050,078	0	-5,131,426
2050	34,609,835	20,318,128	0	-2,718,011	35,436,496	28,422,206	0	-5,494,913

Appendix C. Results by NYISO Zone, Disadvantaged Community Proximity, and Expenditure Tier

C.1 Results by NYISO Zone

Table C-1. Emissions and Energy Savings by Zone, Site Incentive Scenario, Selected Years

NYISO Zone	2027	2030	2040	2050
Cumulative emissions savings (thousand $MTCO_2e$)				
Capital	66	139	275	342
Central	88	188	386	487
Dunwoodie	14	30	60	76
Genesee	33	69	143	182
Hudson Valley	35	73	146	185
Long Island	72	152	310	392
Millwood	2	5	10	13
Mohawk Valley	37	77	154	192
North	7	14	28	37
New York City	72	152	304	379
West	107	230	479	604
Total cumulative savings (thousand $MTCO_2e$)	**532**	**1,130**	**2,296**	**2,890**
Cumulative energy savings (million MMBtu)				
Capital	0.7	1.5	3.1	4.0
Central	0.9	2.0	4.1	5.3
Dunwoodie	0.1	0.3	0.7	0.9
Genesee	0.3	0.7	1.6	2.0
Hudson Valley	0.4	0.8	1.7	2.2
Long Island	0.8	1.6	3.4	4.4
Millwood	0.0	0.1	0.1	0.2
Mohawk Valley	0.4	0.8	1.7	2.2
North	0.1	0.2	0.3	0.4
New York City	0.8	1.6	3.3	4.3
West	1.1	2.4	5.0	6.4
Total cumulative savings (million MMBtu)	**5.6**	**12.0**	**25.0**	**32.3**

Table C-2. Emissions and Energy Savings by NYISO Zone, Carbon Price Scenario, Selected Years

NYISO Zone	2027	2030	2040	2050
Cumulative emissions savings (thousand $MTCO_2e$)				
Capital	90	167	316	413
Central	116	220	431	563
Dunwoodie	18	35	68	89
Genesee	43	82	161	213
Hudson Valley	48	88	169	224
Long Island	95	180	352	466
Millwood	3	6	12	16
Mohawk Valley	49	91	172	223
North	9	17	33	45
New York City	94	178	339	435
West	139	267	534	696
Total cumulative savings (thousand $MTCO_2e$)	**706**	**1,332**	**2,588**	**3,381**
Cumulative energy savings (million MMBtu)				
Capital	1.0	1.8	3.7	4.8
Central	1.2	2.4	4.7	6.0
Dunwoodie	0.2	0.4	0.8	1.0
Genesee	0.5	0.9	1.8	2.3
Hudson Valley	0.5	1.0	2.0	2.6
Long Island	1.0	1.9	3.9	5.2
Millwood	0.0	0.1	0.1	0.2
Mohawk Valley	0.5	1.0	1.9	2.5
North	0.1	0.2	0.4	0.5
New York City	1.0	1.9	3.8	4.9
West	1.5	2.8	5.6	7.3
Total cumulative savings (million MMBtu)	**7.4**	**14.4**	**28.6**	**37.4**

Table C-3. Emissions and Energy Savings by NYISO Zone, Carbon Price+ Scenario, Selected Years

NYISO Zone	2027	2030	2040	2050
Cumulative emissions savings (thousand $MTCO_2e$)				
Capital	96	189	391	640
Central	124	248	503	670
Dunwoodie	20	39	79	102
Genesee	46	91	187	246
Hudson Valley	51	99	206	322
Long Island	102	202	416	574
Millwood	3	7	14	20
Mohawk Valley	52	102	200	255
North	10	19	38	53
New York City	101	200	392	498
West	149	302	624	828
Total cumulative savings (thousand $MTCO_2e$)	**753**	**1,499**	**3,051**	**4,208**
Cumulative energy savings (million MMBtu)				
Capital	1.0	2.1	4.2	5.4
Central	1.3	2.6	5.2	6.6
Dunwoodie	0.2	0.4	0.8	1.1
Genesee	0.5	1.0	2.0	2.6
Hudson Valley	0.5	1.1	2.2	2.9
Long Island	1.1	2.2	4.5	5.9
Millwood	0.0	0.1	0.2	0.2
Mohawk Valley	0.5	1.1	2.2	2.7
North	0.1	0.2	0.4	0.6
New York City	1.1	2.1	4.2	5.4
West	1.6	3.2	6.4	8.1
Total cumulative savings (million MMBtu)	**7.9**	**16.0**	**32.2**	**41.6**

C.2 Results by Disadvantaged Community Proximity

By disadvantaged community (DAC), the concentration of manufacturing energy use in those communities and the specific types of industries determine savings potential. Statewide, 53% of decarbonization potential in the Site Incentive scenario falls outside of DACs. In the densely populated New York Metropolitan area, only 33% does.

Dunwoodie holds the largest share of decarbonization potential within DACs, almost 75% in either scenario, but as one of the smallest zones by base use, it contributes little to potential in absolute terms. Of all the zones, Dunwoodie shows the highest share of base energy use in Food, Fabricated Metals, and Transportation Equipment (66%), and its share of emissions reduction potential (2.6% for Site Incentive and 2.4% for Carbon Price+) exceeds its share of base use (2.2%). New York City holds the next largest share of decarbonization potential within DACs: more than two-thirds in either scenario.

Table C-4. Emissions Reduction and Energy Savings by Disadvantaged Community, Site Incentive Scenario, Selected Years

Community Type	2027	2030	2040	2050
Cumulative emissions reduction (thousand MTCO_2e)				
DAC	250	534	1,093	1,369
Non-DAC	282	596	1,203	1,521
Total cumulative reduction (thousand MTCO_2e)	**532**	**1,130**	**2,296**	**2,890**
Cumulative energy savings (million MMBtu)				
DAC	2.7	5.6	11.7	14.9
Non-DAC	3.0	6.4	13.3	17.4
Total cumulative savings (million MMBtu)	**5.6**	**12.0**	**25.0**	**32.3**

Table C-5. Emissions Reduction and Energy Savings by Disadvantaged Community, Carbon Price Scenario, Selected Years

Community Type	2027	2030	2040	2050
Cumulative emissions reduction (thousand MTCO_2e)				
DAC	329	625	1,222	1,583
Non-DAC	376	707	1,365	1,798
Total cumulative reduction (thousand MTCO_2e)	**706**	**1,332**	**2,588**	**3,381**
Cumulative energy savings (million MMBtu)				
DAC	3.5	6.7	13.2	17.1
Non-DAC	4.0	7.7	15.4	20.3
Total cumulative savings (million MMBtu)	**7.4**	**14.4**	**28.6**	**37.4**

Table C-6. Emissions Reduction and Energy Savings by Disadvantaged Community, Carbon Price+ Scenario, Selected Years

Community Type	2027	2030	2040	2050
Cumulative emissions reduction (thousand $MTCO_2e$)				
DAC	352	706	1,435	1,932
Non-DAC	401	793	1,616	2,276
Total cumulative reduction (thousand $MTCO_2e$)	**753**	**1,499**	**3,051**	**4,208**
Cumulative energy savings (million MMBtu)				
DAC	3.7	7.5	14.9	18.9
Non-DAC	4.2	8.5	17.3	22.7
Total cumulative savings (million MMBtu)	**7.9**	**16.0**	**32.2**	**41.6**

C.3 Results by Energy Expenditure Tier

Table C-7. Emissions Reduction and Energy Savings by Tier, Site Incentive Scenario, Selected Years

Tier	2027	2030	2040	2050
Cumulative emissions reduction (thousand $MTCO_2e$)				
Tier 1	281	597	1,211	1,516
Tier 2	58	124	252	317
Tier 3	193	409	833	1,057
Total cumulative reduction (thousand $MTCO_2e$)	**532**	**1,130**	**2,296**	**2,890**
Cumulative energy savings (million MMBtu)				
Tier 1	3.0	6.3	13.1	16.7
Tier 2	0.6	1.3	2.8	3.5
Tier 3	2.0	4.3	9.1	12.0
Total cumulative savings (million MMBtu)	**5.6**	**12.0**	**25.0**	**32.3**

Table C-8. Emissions Reduction and Energy Savings by Tier, Carbon Price Scenario, Selected Years

Tier	2027	2030	2040	2050
Cumulative emissions reduction (thousand MTCO2e)				
Tier 1	373	704	1,365	1,776
Tier 2	77	146	285	374
Tier 3	255	482	938	1,231
Total cumulative reduction (thousand $MTCO_2e$)	**706**	**1,332**	**2,588**	**3,381**
Cumulative energy savings (million MMBtu)				
Tier 1	3.9	7.6	14.9	19.2
Tier 2	0.8	1.6	3.1	4.1
Tier 3	2.7	5.2	10.6	14.0
Total cumulative savings (million MMBtu)	**7.4**	**14.4**	**28.6**	**37.4**

Table C-9. Emissions Reduction and Energy Savings by Tier, Carbon Price+ Scenario, Selected Years

Tier	2027	2030	2040	2050
Cumulative emissions reduction (thousand $MTCO_2e$)				
Tier 1	400	796	1,632	2,353
Tier 2	83	165	335	443
Tier 3	271	538	1,083	1,412
Total cumulative reduction (thousand $MTCO_2e$)	**753**	**1,499**	**3,051**	**4,208**
Cumulative energy savings (million MMBtu)				
Tier 1	4.2	8.5	16.9	21.5
Tier 2	0.9	1.8	3.6	4.7
Tier 3	2.8	5.8	11.8	15.4
Total cumulative savings (million MMBtu)	**7.9**	**16.0**	**32.2**	**41.6**

Endnotes

[1] The study covers the manufacturing NAICS codes 31–33 and does not include NAICS codes 11 (agriculture), 21 (mining), 22 (utilities), and 23 (construction).

[2] This report assumes that New York State will stay on track with targets set forth in the Climate Act, particularly, the goal of achieving a zero-emission electric grid by 2040. As a result, energy efficiency measures that reduce electricity usage stop producing emissions savings over time.

[3] The study initially considered other types of hydrogen, but determined that green hydrogen had the highest adoption potential. Green hydrogen qualified for production tax credits not available to blue hydrogen (which is conventional production with CCUS). As a result, the Phase One potential study always selected green hydrogen, offering higher savings and lower cost, over blue hydrogen. For simplicity, the Phase Two study analyzes green hydrogen only.

[4] Stock may become available for new adoption of previously implemented measures as those measures reach the end of their EUL. In this study, most measures have measure lives that exceed the study time frame, resulting in minimal retirement and replacement.

[5] Feasibility refers to the fraction of baseline equipment for which the carbon reduction measure is technically feasible from an engineering perspective. Because the study team cannot characterize every industrial process with precision, they may find, for example, that infrared drying is not feasible for all drying applications in the food industry. This factor captures limitations to measure installation beyond those represented in other factors.

[6] This study assumes that New York State will achieve targets set forth in the Climate Act, specifically a zero-emission electric grid by 2040.

[7] In the relevant charts, Fuel Oil and HGL fuel savings are combined and shown “Oil” because together they represent only about 3% of total baseline energy consumption in the industrial sector.

[8] Site incentives interact with prices because the incentive is solving for IRR.

[9] The Stock Study breaks out consumption by end use or fuel type. While this breakout represents a useful first cut at describing energy use, the study team refined these into more granular processes or equipment to identify specific savings opportunities using secondary sources. Appendix A provides further details on the secondary sources used.

[10] Geocoding converts a text string representing a physical location into latitude and longitude coordinates that can be visualized in geographic space along with its associated data.

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